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Editorial

For the benefit of readers who may not have seen it elsewhere, we reprint below the text of an announcement issued by the Council of the University College of the West Indies and the Governing Body of the Imperial College of Tropical Agriculture in September 1958:

'It is widely recognized that a degree course in Agriculture should be available in the West Indies, and for some time the authorities of the two Colleges have considered how to provide it. The Governing Body of the Imperial College of Tropical Agriculture has recently proposed that the Imperial College should merge its identity in the University College of the West Indies and become its School of Agriculture. The Council of the University College has welcomed the proposal and is discussing with the Governing Body of the Imperial College the means of giving effect to it in the near future. The degree course would replace the present course for the Diploma of the Imperial College of Tropical Agriculture, but the other activities of the Imperial College, including its post-graduate teaching and research, would be continued in Trinidad under the auspices of the University College.

'At the request of the two Colleges the Secretary of State for the Colonies has agreed to the secondment of Sir Stephen Luke, K.C.M.G., from the Colonial Office to assist them in the preparation of a scheme and in the conduct of negotiations both in London and in the Caribbean for putting it into effect.'

It only remains to reassure our readers that there is no intention that these arrangements shall interrupt the publication of this journal.

Mechanized Rice Production at the Mahaicony-Abary Scheme, British Guiana

E. G. Giglioli

Agricultural Manager, British Guiana Rice Development Co. Ltd

The Mahaicony–Abary Rice Development Scheme is sited on the Northern Coast of British Guiana in the flood plain lying between the Mahaicony and Abary rivers at a distance of six miles from the coastline.

An area of 11 000 acres of periodically flooded savannah land was brought under control by empoldering in 1943, in an attempt to make up the shortfall in West Indian rice requirements caused by the Japanese occupation of Burma.

It was realized that an immediate expansion of acreage would not be possible using the traditional manual methods of cultivation because of the low population in the area, and it was therefore decided to attempt to mechanize production. Four thousand acres in the polder were set up as a Government-run mechanized rice farm and the surrounding private owners in the area were encouraged to make use of its machinery.

There was practically no local experience of mechanized rice growing to draw upon at the time of establishing the Mahaicony–Abary Rice Development Scheme (MARDS). A large scale attempt at mechanized rice production had been carried out just before 1914 on the neighbouring savannahs of Western Berbice by an American concern. The reasons for its very brief existence are not known, but its failure is thought to have been due to lack of finance.

A few tractors and threshers had been used by farmers in the Colony, particularly in the area between the Mahaica and Berbice rivers, with varying degrees of success. American experience of rice mechanization in the Southern United States was therefore used as a guide, although it was realized from the inception of the Scheme that very considerable modifications of American technique would be required to cope with the much more difficult climatic conditions of British Guiana.

The coastal climate of the Colony consists of two wet and two ill-defined dry seasons. The total yearly rainfall at the Scheme averages 93·61 ± 20·18 in. and rain normally falls on 195 days of the year. The seasons are:

Short dry season — Mid-February to mid-April
Long wet season — Mid-April to mid-August
Long dry season — Mid-August to mid-November
Short wet season — Mid-November to mid-February.

The most striking characteristic of rainfall records in British Guiana is the very large and frequent deviations from the mean. This is particularly noticeable in the short dry and short wet season (*Table 1*).

Table 1. Mean monthly rainfall at the MARDS and standard deviations, 1946–57

Month	*Mean (in.)*	*Standard deviation (in.)*	*Month*	*Mean (in.)*	*Standard deviation (in.)*
January	10·48	±6·11	*July*	11·51	±3·92
February	5·46	2·91	*August*	7·25	4·45
March	5·37	4·89	*September*	2·93	2·00
April	6·50	5·53	*October*	3·50	2·13
May	11·86	3·93	*November*	6·72	4·82
June	12·22	3·36	*December*	9·78	6·31

Two crops of rice per year are grown in the Colony. The spring crop, or short crop, is sown in November–December and reaped in March–April and the autumn crop, or big crop, is sown in March–May and reaped in September–November. At the MARDS the spring crop has never been important, the policy being to concentrate on the better yielding autumn crop.

The solution to successful mechanization of the autumn crop lies basically in the evolution of a system of management sufficiently flexible to deal with the extraordinary variability of the rainfall in the key months of March and April, where the deviations from the mean amount to 91 and 85 per cent of the means respectively.

The Mahaicony–Abary Scheme lies on the very eroded watershed between the two rivers from which its name is derived. The land is flat and is intersected throughout by numerous natural drainage channels, or creek-hands, each of which drains its own watershed. Maximum differences in land level within the 11000 acres empoldered do not exceed 24 in. The irregularity and meandering nature of the creek-hands is such that no uniform gradient over large areas is found and it is frequent to have the full range of level differences within one 50 acre field.

The polder is roughly square in shape. The western side lies along the Mahaicony river, the eastern side along the Abary and the northern and southern sides stretch from river to river. The length of side is of approximately four miles. Splitting the polder down the middle and running parallel to the two rivers from south to north is the main drainage canal which discharges into the Atlantic, approximately six miles north of the northern limits of the polder. Subsidiary east to west canals cut across the polder to sluices on both rivers. At one of these sluices, at the southwestern corner of the Scheme on the Mahaicony, are located two diesel-driven pumps with a total capacity of 160 tons per minute. The pumps are capable of providing both drainage and irrigation through an arrangement of sluices. The rated run-off per 24 hours by gravity drainage is 0·50 in. The new land settlements in the Colony are being based on a run-off of 1·50 in. per day, while the mechanized rice Scheme at Nickerie in Suriname has a pump-off of 2·75 in. per 24 hours.

The main grid of canals with the relevant sluices and pumps are owned, operated and maintained by a statutory body, the Drainage and Irrigation Board, which defrays expenses by levying a *pro rata* charge on all land owners within the empoldered area. The individual proprietor is responsible for all minor works on his own land.

The drainage and irrigation system at Mahaicony–Abary is unique in the Colony because of its dual purpose nature. All canals were designed to be used as both drains or irrigation channels. At the time the Scheme was laid down little was known about the water requirements of mechanized rice production, speed of execution was essential and it was thought that the simpler and cheaper dual purpose layout might prove to be more suitable for rice than the complex and expensive traditional system required for sugar.

Experience has shown that dual purpose drainage and irrigation is totally unsuited to mechanized rice production as it lacks the basic requirement of flexibility to variable weather conditions. For optimum elasticity to the vagaries of weather, water control on an individual field basis is essential; with a dual purpose system the minimum land unit of management is the whole empoldered area. The picture is further complicated when the conflicting water requirements of hundreds of individual proprietors within the polder have to be considered.

The western half of the Mahaicony–Abary Scheme was laid out in two blocks, each surrounded on four sides by canals. The blocks were subdivided into rows of 50 acre fields. The fields were rectangular and measured 1 200 ft × 1 800 ft. Small field drains ran along the two long sides of the field and connected up with the canals surrounding the block.

With this layout 21 fields in the two blocks, covering 47 per cent of the total acreage, had no direct access to a major canal. Water could only find its way in or out of these fields by passing through other fields.

The eastern half of the Scheme was laid out in 60 to 80 acre rectangular fields with a standard width of 600 ft and lengths varying between 3 000 and 6 000 ft. Each field in this area abutted with both shorter sides on a major canal.

Large regular-shaped fields were thought to be most suited to economical performance of machinery. The geometrical layout of the Scheme was carried out before the area was surveyed. Very marked differences in level were found in many fields. The original field size and ratio between width and length has been found to be unsatisfactory and difficult to handle. Changes in the geometrical layout have not been possible because of the grid system on which the main canals are laid.

Over the past four years considerable modifications in field size and width-to-length ratio have taken place. Fields between 18 and 20 acres with a width of 300 ft and a length of 3 000 ft have proved to be amenable to adequate water control, without losing their suitability to mechanical handling. A width of less than 300 ft makes cross cultivation very expensive.

CULTIVATION TECHNIQUES

At the MARDS the primary cultivation implement is the trailed mouldboard plough. In the early days of the Scheme this tool was not favoured and primary cultivation was carried out with disc-ploughs or more frequently with one-way discs. The lack of popularity of the mouldboard was found to be due to the size of plough employed. Only 4-bottom ploughs, convertible to 3-bottoms, were used. The 45 to 50 h.p. tractors mounted on steel wheels were overloaded when pulling 3-bottom 14 in. ploughs, and

stoppages were frequent. The ploughs were converted to 2-bottoms with very successful results.

The standardization on disc-implements for primary tilling meant that cultivation could only be carried out when the land had dried off sufficiently to allow them to work. Thus all operations, whether primary or secondary, were concentrated in the very short period of reliable dry weather available in February–March–April. Adequate weathering of the soil was not possible and the last stages of land preparation were often interrupted by the onset of the mid-year rains. Many tractors working for uneconomically short periods were necessary. The need to hurry all operations before the beginning of the rains favoured a very superficial primary cultivation.

The 2-body mouldboard plough gave excellent results when the land was saturated with water, providing a firm bottom was available. When the land became hard and fairly dry the implement was not successful as depth control was not possible. Since 1954 the mouldboard plough has been the standard implement for primary work.

Cultivation for the autumn crop begins in the January rains, the objective being to complete all ploughing by the end of February and thus reserve the limited dry weather available for finishing operations, which cannot be carried out on wet soil. All ploughed land gets an opportunity to weather properly, but has not enough time to produce a thick vegetative growth, as happens when fields are ploughed in November–December and left over to the spring.

The normal ploughing depth is 4 in. Good inversion and burial are essential for red rice and weed control, as well as to promote drying of the land and facilitate subsequent operations.

The correct type of implement has proved to be a shear-plough, with a relatively long slow turning body, and width to depth ratio of not less than 2:1. Disc coulters have proved essential. Excellent work has been obtained by attaching to the ploughs burying chains with a weight to length ratio of 1:5 lb/ft. Skimmers have given good results, but have proved difficult to use under field conditions, due to the necessity for frequent re-alignment.

Ploughing and all cultivations involving the displacement of soil are carried out to the centre of the field along its long axis to promote run-off. The common practice amongst rice farmers in the Colony is to cultivate to the outside of the field, producing in time a saucer-like effect. Attempts to gather in lands along the narrow axis of the field were abandoned as a series of depressions running across the field were produced which remained very soft and increased in extent with the years.

Secondary cultivations normally consist of one or more one-way discings or heavy disc-harrowings followed by spike harrowing. If one-way discs are used in either a primary or a secondary capacity they are always followed up by a disc or spike harrowing for firming purposes. Unless this is done a spongy seed bed is produced which is very difficult to drain at harvest. Experience has shown that too fine a tilth is undesirable as it favours the maximum germination of the volunteer rice in the soil and a high incidence of red rice in the crop.

Seed is sown by manual broadcasting or by mechanical drilling at a standard seed rate of 70 lb/acre. Drilling has been abandoned of late due to

the unsatisfactory performance of the seed-drills on the rough seed bed that has been found desirable. Covering of broadcast sown seed by light harrowing has given good results when a fairly long dry interval occurs between sowing and the inception of the mid-year rains. If heavy rains fall immediately after the covering operation, the seed fails to germinate. Post-sowing harrowing is no longer carried out as a routine operation because of the high risk involved. Germination of the seed by flooding of the field is not a practical proposition due to the inflexibility of the drainage and irrigation system. There is always a high probability that severe rainfall will coincide with the flooding operations, with the result that the seed remains submerged under excessive water depths for too long a period.

Between 1951 and 1957 a long series of trials aimed at determining the optimum seed rate for dry sowing has been carried out. Seed rates varying from 27 to 140 lb/acre have been tested with very inconclusive results due to the presence of a large reservoir of volunteer rice in the soil.

The technique of wet seed-bed cultivation with wheeled tractors was discovered at the MARDS more or less accidentally in 1947. A very heavy infestation of weed manifested itself in an area of about 300 acres, previously cultivated and sown in the conventional manner. Tractors pulling disc-harrows were sent in to try and destroy the weed. An extremely effective job was done and no difficulty experienced. The possibilities of using the technique as a method of seed-bed preparation were not seriously considered until very bad weather in the spring of 1948, when over 25 in. of rain was recorded from 1 March to 30 April, made wet cultivation the only solution.

The operation is carried out by steel wheel tractors of the 45 to 50 drawbar horsepower class pulling the front section of a medium to light double disc-harrow. In addition to the harrows steel pipes of 5 in. diameter and 12 ft length are used for the final levelling. With four to six inches of water on the field, harrowing is done first in one direction and then in the other, each tractor following the preceding one with either right or left wheels in between the tracks made by the one in front. This overlapping procedure was adopted because the tractor wheels were found to make a greater mark than the harrows. As many passes over the land are given, usually four to six, as are necessary to reduce the top four to six inches of the soil to a soft creamy puddle. The levelling pipes are then attached to the rear of the harrow and one final pass is made to remove the wheel marks.

The most important pre-requisite for this type of cultivation is adequate water control. Too much hinders the incorporation of vegetative growth with the soil by allowing it to float to the surface and too little causes clogging of the wheels and harrow discs making free movement difficult.

Various manual sowing methods have been used. Dry seed has been broadcast through water and the water withdrawn after 24 to 48 hours, pregerminated seed has been broadcast through water which has subsequently been drained off, and pregerminated seed has been broadcast through water which has been allowed to stand. All systems have proved satisfactory under given conditions. Pregerminated seed is more flexible than dry seed. Whether water is left on the field or not after sowing with pregerminated seed is largely determined by the water control available and

the prevailing weather. Under optimum conditions withdrawal of the water after sowing is preferable as the risk of seedling drift is minimized.

Transplanting has never been done, except for seed production, as its cost is nearly three times that of pregerminated seed and there is no large labour supply available. A system of broadcasting young plants, developed in the Far East, is now being tried and shows promise.

A seed rate of 80 lb/acre is used for pregerminated sowing. Rates as low as 40 lb/acre have been successful on small plot trials but, due to the high seedling mortality in the field, it has not proved possible to reduce the standard rate under commercial conditions.

Wet cultivation is the only method by which cultivation programmes, so far as the predetermined total acreage goal for any year is concerned, can be adhered to, due to the variability of weather in the spring. The percentages of the total acreage that were wet cultivated between 1951 and 1957 respectively were: 48, 2, 86, 20, 56, 11 and nil with a 7-year mean of 31 per cent. An examination of the rainfall in March between 1951 and 1957 and of the proportion of wet cultivation carried out in each crop over the same period showed a highly significant positive relationship amounting to 0·90.

Wet cultivation is also the most reliable existing method for rapid reduction of the incidence of red rice. Taking the 1951–56 red rice index for dry-shallow cultivation as standard, wet cultivation, with good water control, has resulted in a 74 per cent drop in the red count; the same technique, with poor hydrological conditions, has only reduced the index by 31 per cent. The effect of wet cultivation on red rice in the soil is through its inhibiting action on germination, so long as the land is not allowed to dry out. There are indications that prolonged periods of wet cultivation have some reducing effect on the reservoir of volunteer rice in the soil.

It has been found at the Scheme that unless water is moved frequently and vigorously through a dry sown crop marked signs of 'burning' followed by stunting, water weevil (*Lissorhoptrus* sp.) infestations and loss of condition and growth occur. Wet cultivated crops are much more resistant to this condition and appear to need only about half the amount of water movement.

Wet cultivation is very expensive, the cost being determined by the number of passes necessary to produce a seed bed. The cost per passage over the field increases steeply with every pass, as conditions get more and more difficult. Repeated passages also increase the degree of silting of all waterways; the smaller drains are sometimes obliterated in one season.

The first three weeks after sowing are extremely critical as the seedlings are liable to drift and drowning through excess water, to drying out through lack of water, to being killed by excessive temperatures where water lies in shallow pools and to destruction by wild ducks. The varieties grown are subject to lodging and wet cultivation has been found to aggravate this propensity.

Wet sown crops, through a combination of impaired drainage, heavy lodging and the softness of the land have proved very susceptible to bad weather at harvest. In the exceptionally wet year of 1954 just over half of the wet sown acreage could not be reaped compared to only 10 per cent of the dry cultivated area (*Table 2*).

Table 2. Effect of wet weather on mechanical harvesting of wet and dry sown rice

Method of sowing	Acreage			% Total acreage sown lost at harvest
	Sown	Reaped	Lost at harvest	
Dry	3234·9	2888·6	346·3	10·70
Wet	824·6	396·8	427·8	51·87

For the period 1951–56, during which both wet and dry cultivations were carried out in every year, the overall mean yield from wet cultivation at the Scheme amounted to 12·77 bags of paddy/acre (equivalent to 1 738 lb/acre), while the yield from dry cultivation was 12·57 bags of paddy/acre (equivalent to 1 760 lb/acre). The margin in favour of wet cultivation at current paddy prices is worth $1.36 per acre, which does not meet the increased costs of the technique.

A small plot trial was carried out for four years to determine the relative worth of various methods of sowing. Water control on the trial was excellent and none of the difficulties inherent in wet cultivation in the field were encountered. The mean yields for the four systems over the four years were: 16·39 bags/acre from drilling, 15·80 bags/acre from dry broadcasting, 18·82 bags/acre from pregerminated broadcasting and 19·98 bags/acre from transplanting. Both wet systems were significantly better yielders than the two dry methods. The 3·02 bags/acre margin in favour of wet broadcasting relative to dry broadcasting, equivalent to an increase in gross revenue per acre of $20.53, is highly economical.

Table 3. Effect of four years of wet cultivation on yield of rice growing under field and small plot conditions

Conditions of growth	Yield/acre (140 lb bags)			
	1st year	2nd year	3rd year	4th year
Field	19·09	11·32	12·80	7·03
Small plot	14·35	18·14	17·42	25·35

Prolonged wet cultivation under field conditions has led to very serious drops in yield (*Table 3*). An area of 175 acres, subdivided into four fields, cultivated wet for four years gave a yield of 19·09 bags/acre in the first year which fell in the fourth year to 7·03 bags/acre. In the small plot sowing trial, mentioned above, there was a strong tendency for the yield to increase with successive wet cultivations. The progressive and rapid fall in yield from wet cultivation in the field is not due to a decrease in the inherent yielding ability of the land through prolonged use of the technique. It is a result of the breakdown of the cultivation method when faced with ever deteriorating soil–water conditions. Wet cultivation on land that has already been so treated in the previous year is very difficult. By the fourth year the tractors can hardly move through the field, with the result that the quality of seed-bed produced bears no relation to that achieved in the first year. Harvesting

troubles parallel difficulties of cultivation. On small plots, with perfect water control, prolonged wet cultivation does not run into these complications.

The remedy is thought to lie in better water control at field level and in the evolution of a different technique of cultivation requiring fewer passages of the machines over the land. Work on these lines is now in progress.

CHOICE OF VARIETIES

Until 1951 the entire acreage planted at the Mahaicony Abary Scheme was sown to the best known local variety No. 79. Between 1951 and 1955 substantial areas of a newer native variety, D 85/42, were grown. Both varieties are characterized by very abundant straw production, heavy tillering, extreme susceptibility to lodging and easy shattering of grain. Both were bred for transplanting and manual reaping and threshing and are not suitable for mechanical cultivation. The straw and the grain are very abrasive and serious wear on combine augers and elevators is caused.

The varieties grown are sensitive to photoperiodism. In small plot trials and under commercial growing conditions crops sown between late February and mid-July, a spread in sowing dates of 20 weeks, have reached maturity in September–October, the maximum range between reaping dates being eight weeks. The strong tendency towards simultaneous ripening of the varieties used, irrespective of their sowing date, allows for very little spread of the harvest. An excessive number of combines for a relatively short period is required to reap the crop at optimum grain-moisture conditions. In practice the aim is to be sufficiently equipped to reap 25 per cent of the crop slightly green and 25 per cent slightly over-ripe so as to get half of the crop at optimum.

Trials at the Scheme have shown that wet cultivation accelerates ripening by 10 to 20 days compared to dry cultivation and that variety 85/42 ripens from one to two weeks earlier than No. 79. Widening the harvesting period by a combination of the two varieties and the two methods of sowing is possible with first class water control, as it is necessary that the wet cultivated 85/42 be sown in mid-February, followed by dry sown 85/42, wet sown No. 79 and finally, in late March, by the dry cultivated No. 79. Under existing conditions of drainage and irrigation it is not possible to flood for wet cultivation in early spring without jeopardizing all subsequent dry cultivations, nor would it be feasible to keep an adequate supply of water available to the early cultivated wet sown rice while attempting to carry out dry cultivation. In field practice the later maturing dry sown rice is always cultivated first, to take advantage of the dry weather in the spring and the earlier ripening wet cultivated rice is sown later in the May rains, with the result that the entire crop reaches optimum maturity over an extremely narrow period.

Trials have been carried out with Blue Bonnet 50, an American variety, used extensively at one time on the Dutch schemes in Suriname. The variety is non-lodging, non-tillering and produces very little straw, but under Mahaicony–Abary conditions it has proved a poor yielder. The Department of Agriculture has a breeding programme aimed at producing varieties more suited to mechanical handling. The first results of this programme are now being tested on a field scale at Mahaicony–Abary.

CONTROL OF RED RICE AND WEEDS

Rice soil conditions on the coastlands of British Guiana are such that dry seed-bed preparation is not economically possible when draught animals are the sole source of power. The introduction of tractors allowed very large acreages to be dry cultivated and sown. The trend away from wet seed-bed preparation, whether followed by transplanting or broadcasting of pre-germinated seed, has been constant and ever increasing over the last 10 years.

Wet cultivation is known to suppress red and volunteer rices and provided uninfested seed is used, the red rice incidence of the resulting crop remains negligible. Dry cultivation has no inhibiting effect on the germination of volunteer seed in the soil and growers in the areas where mechanization first started did not realize the importance of red-free seed until faced with massive infestations. At the Mahaicony–Abary Scheme, where the gravity of the red rice problem was first appreciated in 1950 and work on remedial measures begun, the normal incidence of red rice in a dry sown crop is 13 per cent. Amongst neighbouring farmers values of 60 per cent are frequent.

The practice of taking 'cheap' volunteer spring crops and of using commercial paddy as a source of seed, still very common among mechanized rice farmers in the Colony, was stopped on the Scheme in 1952. A long series of trials was initiated in 1951 to find methods of controlling the incidence of red rice.

The classical American system of exhaustion of the soil reservoir of seed by repeated off-season cultivations failed to achieve the desired results due to the very uncertain weather and the generally poor drainage. While no difficulty was found in producing a thick stand of volunteer growth by cultivation after harvest, getting back on the land a second time in order to destroy the growth and produce another crop of drop seed rice proved impossible as the land was waterlogged. In all cases the first growth brought up reached maturity before conditions were good enough to allow further cultivation, resulting in an increase in the reservoir through grain shattering. The technique is thought to have possibilities if carried out on well drained land and supplemented by the use of modern grass-killing weedicides.

Prolonged and very intensive grazing of volunteer growth by cattle did not have any significant effect on the incidence of red rice in subsequent crops. There were indications that the trampling of cattle on the soft land drove the seed deeper into the soil, thus in effect extending the depth of infestation, which is normally confined to the top four inches of soil constituting the ploughing zone.

Attempts at chemical control by pre-sowing application of both selective and non-selective weedicides were disappointing. The germination of the seed sown four weeks after spraying was severely depressed while the deeper-seated and later germinating red rice was unaffected. Recent preliminary trials with the sodium salt of dichloropropionic acid have shown promise when the weedicide is used in combination with the system of promoting germination of the volunteer reservoir.

Significant reductions in the incidence of red rice, through partial destruction of the soil reservoir, have been obtained by increasing the ploughing depth to a minimum of eight inches. The red rice controlling

effectiveness of this method is entirely dependent on complete inversion of the land. Trials have shown that under prevailing field conditions the viability of red rice seed is drastically lowered in less than a year, when buried at depths greater than eight inches. Complete burial, a vital feature of the technique, is dependent on the equipment used and on soil moisture. Mouldboard ploughs of the type already described have proved most suitable. Soil moisture is the determining factor in the success of the technique. The best results have been obtained when the soil is saturated but firm, allowing easy penetration and possessing a sufficient degree of plasticity to turn without breaking and smear without sticking. The critical range of soil moisture necessary to satisfactory deep ploughing has proved to be extremely narrow; this has been a severe limitation on the usefulness of the method as a red rice controller.

The overall effect of deep ploughing on the incidence of red rice, over six crops, has been to reduce the magnitude of the infestation by 25 per cent compared to normal ploughing. Properly carried out deep ploughing has been found not only to reduce the incidence of red rice in the crop immediately following on the ploughing, but also to have a residual effect in the next year's crop with no further deep cultivation.

The effectiveness of wet cultivation as a suppressor of red rice has already been mentioned.

The most troublesome weeds encountered at Mahaicony–Abary are: *Thallia* sp., *Fymbristylis miliacea*, *Cyperus* sp., *Aeschynomene sensitiva*, *Sesbania sericea*, and *Caperonia castanoefolia*. Work carried out in 1952 on small scale trials showed that control of all these weeds was possible using 2,4-D weedicides; the problem was one of large scale application in wet rice fields. In 1956 and 1957 very large trials were made using the Swingfog fogging and spraying machine. In the latter year over 900 acres of flooded rice fields were sprayed with the Swingfog using trimethylamine of 2,4-D. Excellent control of *Cyperus* sp. was observed at applications of three quarters of a pint of weedicide per acre, equivalent to ½ lb 2,4-D acid, at an all-in cost of $1.13 per acre. Similar results have been obtained against *Fymbristylis miliacea* and *Caperonia castanoefolia*. Only partial control of *Thallia* sp. has been achieved. This weed is sheltered by the rice up to its last stages at which time it cannot be sprayed as the rice is in flower. Pure stands of *Thallia* sp. in creek-hands or along canal edges have been controlled using two pints of amine/acre. Weeds sensitive to 2,4-D, but only partially controlled by the Swingfog, have recently been sprayed with an equally portable power sprayer, delivering slightly higher volumes, with very promising results.

Within the last two years a distinct increase in the grass component of the weed flora has been noted, mainly *Echinochloa colonum* and *E. macrostachya*. Whether this is due to the very dry weather in the last three years or to the improved drainage is not clear.

No great trouble has been experienced with pests or diseases at Mahaicony–Abary. The pests encountered are, with one exception, common to all systems of rice growing in the Colony and have not proved to be of any significance. The rice water-weevil (*Lissorhoptrus* sp.) appears to be very much more prevalent and serious in dry sown rice than in either wet sown or transplanted rice. The insect is easily controlled by draining

the affected area in serious cases or by mere horizontal movement of water in slight cases. The movement of water is not easy in a layout such as the one at Mahaicony–Abary and it is nearly impossible for the bulk of the mechanized rice farmers who are dependent on rainfall for irrigation. At the Scheme a general water movement throughout the fields twice a month between June and August, when the pest is most likely to manifest itself, has proved satisfactory with dry sown crops; with wet sown or transplanted rice the water need only be moved once a month.

HARVESTING AND YIELDS

Water is withdrawn from the crop when the ears bend over. This usually occurs three to four weeks before the beginning of harvest. In very rainy weather or with wet cultivated crops the water is drawn off seven to ten days earlier.

In the early days of the Scheme reaping was carried out by reaper-binders and stationary threshers. This system was unsuccessful and was very rapidly discarded in favour of small pull-behind combines and self-propelled combines. The track-laying self-propelled machines were used to open up the fields for tractor-drawn reapers and generally to do odd jobs that the smaller combines could not accomplish. A succession of very wet harvests in 1953 and 1954 showed the superior adaptability of the self-propelled combines to very bad conditions. Within the last three years the Scheme has standardized on self-propelled machines with excellent results, a trend which is being very closely parallelled by neighbouring farmers.

The standard type used is track mounted, with a 14 ft auger table. Pick-up reels are essential to deal with the lodged crops encountered. The paddy is bagged and dropped in the field. Transport of the bags from the field to the nearest dam has proved extremely difficult at times through bad weather. Ox-drawn carts, sheet-metal sledges drawn by tractors, platforms built on to the rear of tractors, trailers and lorries have been used depending on the weather and the softness of the land. Transport from the dam-side to the mill is done by tractor-drawn trailers or by lorries.

Yields in the Colony are expressed in terms of bags of 140 lb net weight of clean, dry, well winnowed paddy. The autumn crops grown at the Mahaicony–Abary Scheme between 1945 and 1957 have yielded an average of 12·22 bags/acre. The peak yield was obtained in 1952 with 16·16 bags/acre and the lowest in 1957 with 8·76 bags/acre. The 1945–57 Colony yield amounted to 16 bags/acre.

A large series of trials has been laid down at the Scheme since 1951 to investigate the possibilities of increasing yield through the use of fertilizers. The responses have been very erratic from year to year, the most consistent response being to applications of phosphate in the form of superphosphate. Field scale manurial trials have been disappointing both agronomically and economically. The most constant yield increases have been obtained from the deep ploughing operations carried out to control red rice. The action of deep ploughing on yield was found to be much more reliable than its effect on the incidence of red rice. The yield-increasing effectiveness of deep cultivation appears to be governed by depth only and not by any of the other factors determining its usefulness as a red rice controller. Deep-ploughing

has yielded an average of 2·70 bags paddy/acre more than shallow ploughing, equivalent to a net increase in revenue of $15.36/acre.

Experience at Mahaicony–Abary has shown that the pre-requisite to higher yields and lower costs of production for mechanized rice growing in order of decreasing priority are: water control, red rice control and a range of varieties suitable to mechanical handling. Red rice control is not feasible without water control and the introduction of new varieties is largely pointless unless the red rice and volunteer rice reservoir in the soil is first cleaned up.

WIDER INFLUENCE OF THE SCHEME

The Mahaicony Abary Scheme is the cradle of mechanization in the Colony. Mechanized production has spread outward from the Scheme and is now the predominant cultural technique on the Coastal savannahs lying between the eastern bank of the Mahaica and the western bank of the Berbice rivers.

The last agricultural census, carried out in 1952, showed that 87 per cent of the acreage cultivated in the area was broadcast sown, a method of sowing characteristic of mechanical cultivation, while only 29 per cent of the crop grown in the rest of the Colony was broadcast. At the time two thirds of the tractors employed on rice cultivation in the country were reported between the Mahaica and the Berbice. Similarly 34 per cent of the crop in the area was combine-harvested compared to 8 per cent in the rest of the Colony and three quarters of the combines in British Guiana were located in the district.

No detailed statistics on the progress of rice mechanization in the Colony are available after 1952, but an indication of the increasing importance of machinery in the industry can be obtained from the tractor registrations. In the five year period 1948–52, 430 tractors were registered; in the next quinquennium the number registered increased by 3½ times to 1508 units.

Mechanization between the Mahaica and Berbice rivers, where ecological conditions are very similar to those on the Scheme, has closely followed the pattern established at Mahaicony–Abary. On the Corentyne coast, where the latest expansion in the use of machinery is taking place, a type of partial mechanization has been evolved. Because of the high population pressure, better water control and smaller size of holdings, the tractors have been fitted into the traditional method of cultivation purely as a replacement for draught oxen. The shift to dry cultivation and broadcast sowing, with all the attendant problems which followed mechanization between the Mahaica and the Berbice, has not been apparent in the Corentyne. Harvesting remains normal, the tractor being used in place of the bullocks which thresh the grain by trampling.

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Studies on Seed Germination and Seedling Growth in Rice (Oryza sativa *L.*)

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A low percentage germination of rice seed in Malaya can be caused by a number of factors. Thus Dore (1955) showed that loss of viability might result in low seed germination. The failure to use clean seed, and its consequent attack in the soil by micro-organisms, has also been noted as a cause of low germination (Cherewick, 1954).

For the germination of seeds of many plants various physiological factors are of great importance. These factors have been extensively reviewed by Crocker and Barton (1953). Few such investigations of the effect of physiological factors have, however, been carried out with the seeds of either rice or other marsh plants. Edwards (1933) and Morinaga (1926a, b) have investigated the effects of oxygen and submergence on the seed of a number of marsh plants, whilst Barton (1952), Jones (1933), Nagai (1916), Sircar, Das and Lahri (1955), Taylor (1942), and Vlamis and Davis (1943) have carried out similar investigations on rice seed. No investigations have, however, been made on the effects of differences in water supply under natural conditions.

As the nursery techniques used in rice-producing countries vary so much (Grist, 1953), it is of some importance to determine the action of the method of water supply to the nursery bed on the germination and establishment of the seed. In addition to the use of differing water régimes in the seedling nursery it is the practice in many countries to apply heavy nitrogen dressings to the nursery bed. Thus, in places as widely different as Spain (Butler, 1914), India (Sethi, 1952), and the Philippines (Songcuya, 1941) heavy nursery dressings of fertilizers are recommended. The value of this practice has, however, been the subject of some controversy (Grist, 1953; Ignatieff, 1951). The investigations reported here were designed to test the effects of both different water régimes and heavy dressings of nitrogen on the germination and early growth of rice seed in soil. The effect of heavy fertilizer dressings is of special importance, for in dry land crops very heavy dressings of fertilizer are known to reduce germination, whereas in rice, where it is customary to germinate the seed in a nursery bed either covered with water or liberally supplied with sub-soil water, it seems that the high applications of nitrogen are in some way modified by the water régime of the nursery bed.

Experiments were therefore carried out in large 18-in. diameter clay pots in a bird-proof cage in Kuala Lumpur to examine factors which encourage a high percentage germination and establishment of *padi* seed in the soil.

SOME PRELIMINARY EXPERIMENTS ON SEED GERMINATION

Effect of pathogens

A necessary preliminary to carrying out an experiment on conditions, other than pathogens, affecting germination is to determine whether there

are any germination differences between seed dusted and not dusted with fungicide and between seed germinated in the soil and under laboratory conditions.

Two lots of seed of the variety Siam 29,[1] which had been stored in an air-conditioned room, were soaked for 24 hours in distilled water and then dried by blotting with filter paper. The first lot was then dusted with a patent organo-mercury fungicidal dust at a rate of 0·1 g of dust to 20 g of seed, while the second lot remained untreated. Four pots containing old soil of unknown origin were prepared as seed-beds two days before planting the seeds. Two pots were allocated to each of the treated and untreated lots, and 100 seeds were placed upon the surface of the mud in each pot and covered with 1 in. of water. Viability of the treated and untreated seed was determined by germination tests, in Petri dishes, of duplicated lots of 100 seeds from each treatment. Final germination percentages were recorded after nine days, and are given in *Table 1*.

Table 1. Mean percentage germination of padi *seed*

In soil		*In Petri dish*	
Treated	*Untreated*	*Treated*	*Untreated*
96·5	100	96·5	97·5

The data show that the fungicide treatment did not cause any increase in percentage germination and that, in the soil to be used in the main experiments, pathogens were of no importance. It was thus decided that the examination of environmental conditions would be carried out on seed not fungicidally treated.

A test of sowing technique

Experimental methods—The treatments to be examined in the main experiment included that of sowing the seed on the soil surface in moving water. It was necessary to test this technique to determine whether the moving water would cause the seed to shift from position, or even to be lost in the process of the experiment. This method was compared with the sowing of seed on the soil surface, but with stagnant water, and with seed sown under a layer of mud with either stagnant or moving water. The maximum potential germination was determined by germinating a sample of 50 seeds on moist filter paper in a Petri dish. The germination percentages obtained after 15 days are recorded in *Table 2*.

Table 2. Percentage germination under different conditions

Control (filter paper)	*Seeds on surface of mud*		*Seeds covered with mud*	
	Stagnant water	*Running water*	*Stagnant water*	*Running water*
84	16	28	32	20

Each pot was examined daily during the course of the test so that any loss of seed due to the technique would be noticed. No seeds were lost by faulty technique. It was found essential, however, that the first application

of water should be made with care, both for the stagnant and running water treatments. The water was applied to the soil very slowly as a sudden rush of water on to the bare mud was found to wash the seeds away. When a depth of water (stagnant or moving) of about 1 in. had been run on to the mud, the seeds were not liable to float away or be washed off the mud. All water used in this test and the following experiments was obtained from the domestic water supply. Stagnant water treatments were filled with this water to the required depth and no further tap water was added during the experiments. Slight rain showers added sufficient water to these pots to counteract evaporation without disturbing the stagnancy of the water. In the running water treatments tap water moved continuously from one side of the pot over the soil at a rate of about 5 l. per hour. Water depth was maintained by allowing the water to escape from a hole in the side of the pot 1 in. above soil level.

Seed germination under water. A brief discussion—The results obtained in this test of technique are of interest, as the percentage germinations in the soil treatments were lower than those obtained on filter paper. The first test showed that pathogens were absent from the soil used, and thus that reduced germination in this test was due to some other cause.

Although this seed sample was slightly less viable than that used in the test for pathogens, the lower viability shown by the germination percentage on filter paper is insufficient to account for the very low germinations in soil. Sircar, Das and Lahri (1955) have shown that in certain conditions rice will not germinate under water, and that this is possibly due to over-abundance of some auxin-like substance in the endosperm, whilst Barton (1952) has shown that carbon dioxide delays germination in rice seed. Our results could be explained on the same basis as either of these two results.

Table 3. Number and percentage of seedlings in various stages of growth

Seedlings	Treatment			
	Seeds on surface		Seeds covered	
	Stagnant water	Running water	Stagnant water	Running water
With 1 leaf	1	—	7	1
Per cent of total	12·5	—	44·0	10·0
With 2 leaves	5	14	9	9
Per cent of total	62·5	100·0	56·0	90·0
With 3 leaves	2	—	—	—
Per cent of total	25·0	—	—	—
Total	8	14	16	10

In addition to the germination data, the numbers of leaves growing on each of the seedlings were counted at the end of the experiment to assess the vigour of the seedlings under different conditions. The results are given in *Table 3*, and show that the conditions under which plants are grown, apart from influencing the percentage germination of seed, influence the growth of the seedlings. Running water tends to encourage a more uniform growth of the seedlings, a feature of considerable practical importance.

EFFECT OF SEED DEPTH, FERTILIZER AND WATER MOVEMENT ON GERMINATION AND VIABILITY

A $2 \times 2 \times 3$ factorial experiment with two replicates each of 100 seeds was set up in pots in the Kuala Lumpur *padi* cage. All 12 treatments were randomized within each replicate. A daily record of midday soil temperature was taken for all the treatments in one replicate. The experiment was repeated with the same randomization as complete results were not obtained in a first experiment because of damage by rats.

The pots were prepared two days before sowing by puddling the surface of the soil and allowing it to settle. Seeds of Siam 29, which had been stored in an air-conditioned room since harvest, were used in both experiments and were soaked overnight in distilled water before sowing on a 6-in. square area of mud. Treatment levels were as follows:

a_0 Seed not covered with soil
a_1 Seed covered with $\frac{1}{4}$ in. soil
b_0 No fertilizer
b_1 12 g of a NPK mixture (3:1:1 of sulphate of ammonia, double superphosphate and muriate of potash) mixed into soil surface before sowing
c_0 Soil surface moist
c_1 Stagnant water
c_2 Running water.

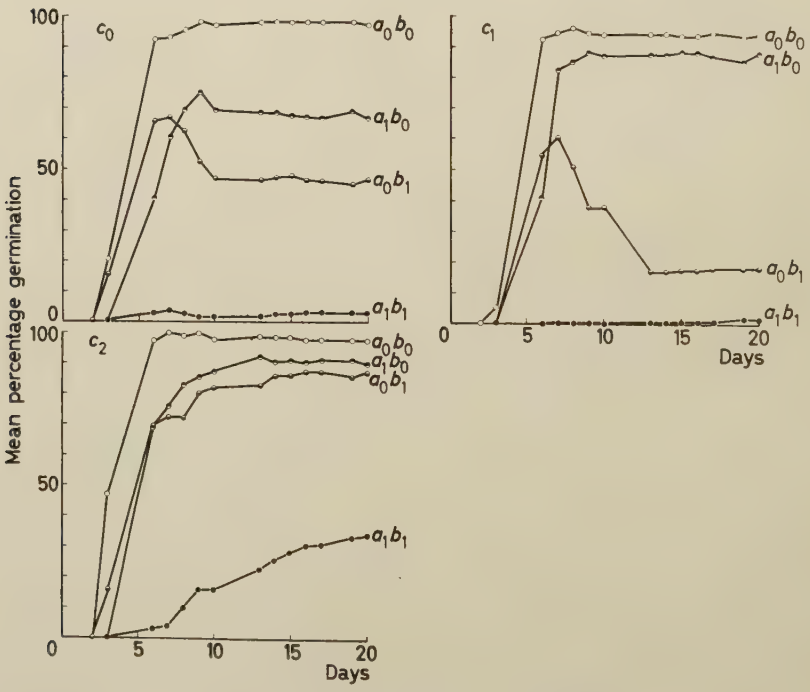

Figure 1. Daily percentage germination of rice seed under different environmental conditions. c_0*: no water;* c_1*: stagnant water;* c_2*: running water;* a_0b_0*: seed not covered with soil, no fertilizer;* a_1, b_0*: seed covered with soil, no fertilizer;* a_0,b_1*: seed not covered with soil, fertilizer;* a_1,b_1 *seed covered with soil, fertilizer*

All combinations of all levels of treatment were used, giving 12 treatments in all.

Daily counts of the number of seedlings established were made in both experiments, and after 20 days the final percentage germination was recorded, together with the weight of the plants in each treatment. The stage of growth of the plants was also recorded by counting the number of leaves on all the plants. It was considered that after 20 days of growth the numbers of seedlings established would have been constant for some days; and this was found to be so.

The results recorded here are those obtained from the repetition of the experiment. Results from the damaged experiment are included where possible and are noted separately.

The daily counts of the numbers of germinated seeds, expressed as percentages of the total number sown, are represented by the curves in *Figure 1*, while the final percentages of seeds established in the undamaged experiment

Table 4. Percentage of germinated seed after 20 days
(Corrected for numbers of seedlings destroyed by rats)

Treatments		c_0	c_1	c_2
		No surface water	*Stagnant water*	*Running water*
a_0b_0	*Seed uncovered; no fertilizer*	43·5	62·0	97·5
a_1b_0	*Seed covered; no fertilizer*	76·0	71·0	95·0
a_0b_1	*Seed uncovered; fertilizer*	53·5	54·5	88·0
a_1b_1	*Seed covered; fertilizer*	8·5	4·5	24·5

are recorded in *Table 5* (a). *Table 4* gives the final percentages of seedlings established in the damaged experiment (corrected for numbers of seedlings destroyed by rats).

Effect of treatment on rate of seed germination

Figure 1 shows the effect of fertilizer and seed depth, in different water conditions, on the rate and percentage of seed germination. The curves show that the maximum number of seedlings is established a few days after sowing, and that after this period there is death of some seedlings in some treatments.

Fertilizer treatment of the uncovered seed, on the moist soil surface (a_0, b_1, c_0) (*Figure 1*, c_0) or in stagnant water (a_0, b_1, c_1) (*Figure 1*, c_1) causes the death of seedlings. This is most pronounced in the stagnant water treatment.

In all water treatments the initial rate of seed germination is higher in the unfertilized and uncovered seed (a_0, b_0) than in the remaining fertilizer and seed depth treatments.

Effect of treatment on final percentage of seedlings established

The final percentage of seed established [*Table 5* (a)] was statistically analysed in order to examine the main effects of individual treatments, and to examine the interactions between the various treatment levels. The data

Table 5 (a). *Mean percentage of germinated seed after 20 days*

Treatments		c_0 No surface water	c_1 Stagnant water	c_2 Running water
a_0b_0	*Seed uncovered; no fertilizer*	97·0	93·5	99·0
a_1b_0	*Seed covered; no fertilizer*	76·5	87·5	90·5
a_0b_1	*Seed uncovered; fertilizer*	46·5	17·5	87·5
a_1b_1	*Seed covered; fertilizer*	3·0	1·5	34·0

were first angularly transformed according to the method of FISHER and YATES (1948), and analysed by the method for a $3 \times 2 \times 2$ factorial experiment given by YATES (1939). The summarized analysis of variance of the transformed data is given in *Table 5* (b).

Table 5 (b). *Analysis of variance of transformed data in Table 5* (a)

Variance	*D.F.*	*Mean sums of squares*
Due to replicates	1	65·67
Between treatments	11	1583·42
Effect of seed cover	1	10521·09*
Effect of fertilizer	1	2577·15*
Effect of water supply	2	1213·18*
Seed cover × fertilizer	1	501·42*
Seed cover × water supply	2	161·28†
Fertilizer × water supply	2	472·45*
Seed depth × fertilizer × water supply	2	62·09 *N.S.*
Error	11	18·81

* Significant at $P = 0{\cdot}001$.
† Significant at $P = 0{\cdot}01$.

The tables distinctly show the strong effect of fertilizer and seed depth, and suggest that these are affected by water supply. The main effects of fertilizer and seed depth are separately tabulated in *Tables 11* and *13* respectively, where the reduction in germination is shown to differ according to the water treatment and either seed depth or fertilizer. The analysis shows that the effects of the various treatment levels are large and highly significant. When the seed is not covered with soil (a_0) and not fertilized (b_0) the percentage of seedlings established is over 90 in all water conditions, while with seed covered and fertilized (a_1, b_1) seed germination is very low.

This contrast between the high (a_1 and b_1) and low (a_0 and b_0) levels of fertilizer and seed depth shows in the analysis as a highly significant seed depth × fertilizer interaction. Similarly, the significant interaction of fertilizer and water treatments is explained by the large differences in the mean reduction in germination due to fertilizer (*Table 11*), where stagnant water causes the greatest reduction and running water the least.

The lower level of significance of the seed depth × water treatment interaction is explained by the absence of differences, in mean decrease in germination between moist soil and running water, in the seed covering treatments (*Table 13*). Stagnant water reduces the decrease in germination due to covering the seed, presumably because the differences in aeration and light as between covered and uncovered seed are reduced by a further covering of stagnant water.

The interactions are also apparent by inspection of *Figure 1*, where germination is reduced to levels below the germination with the zero level of fertilizer and seed depth.

Viability of the seedlings

At the completion of the experiment, seedlings were counted and divided into four categories. The groups were those seedlings with one, two, three or four leaves (excluding the coleoptile). The differences in total leaf number indicate the amount the seedling has grown and the uniformity of

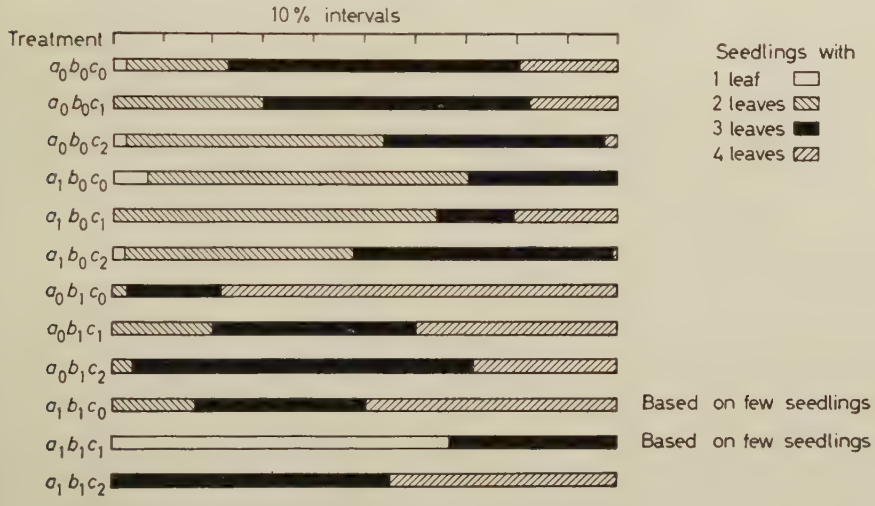

Figure 2. Percentage distribution of seedlings with different leaf numbers. c_0, c_1, c_2 *etc. as for Figure 1*

the seedlings in each treatment. The results are shown diagrammatically in *Figure 2* as percentages of the total number of seedlings in each group.

In all cases with covered seed and no fertilizer (a_1, b_0) there are few seedlings with four leaves, and only in running water is there a high percentage with even three leaves. The previous results have shown that there

is a slightly lower rate of germination of buried seed (*Figure 1*), so the high percentages of smaller seedlings in covered seed treatments must be due to later appearance of the seeds.

Fertilizer treatments (a_0, b_1 and a_1, b_1) give a high proportion of seedlings with three to four leaves, with the exception of the moist surface (c_0) and stagnant water (c_1) treatments where with the seed covered and with the use of fertilizers (a_1, b_1) the seedlings are too few to warrant any but the most tentative conclusions being drawn from the percentage distribution of leaf numbers. In all other treatments the seedling numbers are higher and the proportions in each category more reliable. The control treatments (a_0, b_0, no fertilizer and seed uncovered) show some slight differences in leaf number due to water supply (*Figure 1*). In all three water conditions the majority of seedlings have two or three leaves, but there is an increase in seedlings with two leaves and a decrease in those with three, with the qualitative change from no surface water to running water. A similar change, only in the ratio of three- to four-leaved seedlings, takes place in the fertilizer only treatments (a_0, b_1) where, with the change from no surface water to running water, there is an increase in the number of seedlings with three leaves and a decrease in those with four. This suggests that the effect of water condition behaves in this respect quantitatively, 'increasing' water causing an inhibition in leaf growth. There was no indication in the germination results that water treatments acted quantitatively, as no surface water (c_0) and stagnant water (c_1) were almost the same in effect. The differences in the nature of the action of the water treatment on germination and growth are presumably due to the water treatment altering the environment in more than one way. Thus germinating seed may react to the water movement or some environmental factor altered by water movement, and the growth of the seedlings to the total amount of water available (none c_0, limited c_1 and unlimited c_2). The treatments with no fertilizer and covered seed (a_1, b_0) show a reverse trend, the number of seedlings with three and four leaves increasing and the number of those with two leaves decreasing, with the change from no water to moving water.

Yield of seedlings

All seedlings formed in all treatments were weighed and the mean weight per plant determined. An analysis of the undamaged experiment as a $3 \times 2 \times 2$ factorial did not show any significant effects of individual treatment levels or any significant interaction effect.

EFFECT OF DIFFERENT NITROGEN FERTILIZERS ON GERMINATION AND VIABILITY

Soaked rice seed (variety Siam 29) was planted in pots prepared as for the previous experiment. Seeds were planted 100 to a pot on top of the soil, and running water was supplied individually to each pot. In all, seven treatments were replicated three times in a randomized block arrangement. The treatments, which were applied to the soil before sowing the seed, were:

C.	Control—no treatment
S.A.	Ammonium sulphate (7 g/pot)
S.A.+P.	Ammonium sulphate (7 g/pot) plus double superphosphate

(8·1 g/pot) to give a phosphorus pentoxide content of the mixture equivalent to mono-ammonium phosphate

S.A.+L. Ammonium sulphate (7 g/pot) plus lime (5·7 g/pot) to give a calcium content equivalent to calcium cyanamide

M.A.P. Mono-ammonium phosphate (12 g/pot)

C.C. Calcium cyanamide (7 g/pot)

U. Urea (3·2 g/pot).

In all the treatments except the control the percentage nitrogen in the chemical was the same. The chemicals were all of commercial fertilizer quality. The amount of sulphate of ammonia used in the S.A., S.A.+P., and S.A.+L. treatments was based on the nitrogen content of a standard fertilizer used in our pot experimental work, as a basal dressing. The S.A.+P. mixture contains about 3 to 4 per cent calcium oxide; as this is largely insoluble it will be considered that it has no appreciable effect on germination and seedling growth.

Counts of percentage germination were made daily, and the pH of the soil was measured, before the treatments were applied, at 10 days and at 20 days. The final fresh weight yield of the seedlings was measured at 21 days and a visual assessment of the colour of the plants was made at the same time. Visual assessment was made independently by three observers, who arranged the seven treatments in each replicate in order of greenness, the least green treatments scored one point and the most green seven points. The data thus obtained were statistically analysed as discrete data without transformation. The number of leaves and tillers on each seedling was counted to assess the effect of treatments on the viability of the seedlings.

Effect of nitrogen on establishment of seedlings

The numbers of seed germinated each day in the various treatments are shown in *Figures 3* (a) and *3* (b). The curve for the control treatment is shown in both *Figures 3* (a) and *3* (b) for convenience of interpretation. It is obvious from the curves that the depressant effect of sulphate of ammonia seen in

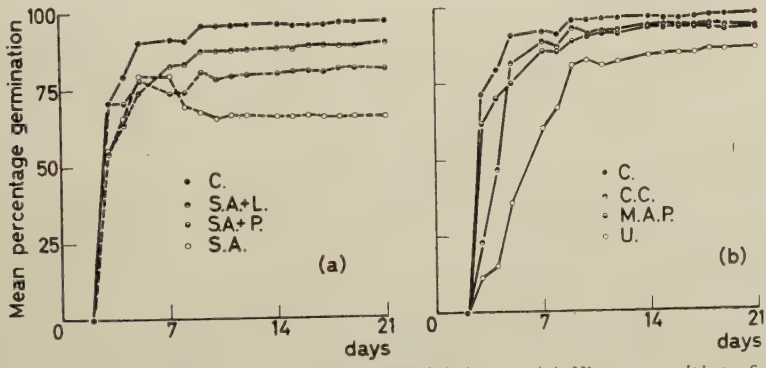

Figure 3. Germination of rice seed in soil with added nitrogen. (a) *Nitrogen as sulphate of ammonia;* (b) *Nitrogen in other forms.* —•—•— *C. Control.;* - - -⊖- -⊖- - *S.A.+L. Sulphate of ammonia+lime;* - - -⊖- -⊖- - *S.A.+P. Sulphate of ammonia+superphosphate;* - - -○- -○- - *S.A. Sulphate of ammonia;* —⊖—⊖— *C.C. Calcium cyanamide;* —⊖—⊖— *M.A.P. Mono-ammonium phosphate;* —○—○— *U. Urea*

the previous factorial experiment in the running water treatments is repeated here. But it is also apparent that this effect can be eliminated by using an alternative nitrogen source (M.A.P. or C.C.) or by the addition of lime to the ammonium sulphate. The addition of double superphosphate to the ammonium sulphate is not as effective in preventing reduced germination as the use of mono-ammonium phosphate as a fertilizer. The use of calcium cyanamide as a source of both nitrogen and calcium has no advantage over adding lime to sulphate of ammonia. The use of urea is nearly as disadvantageous as use of sulphate of ammonia.

Various statistical comparisons have been made on the data for percentage germination at 21 days. The data from each replicate were first angularly transformed according to the table given by FISHER and YATES (1948) and statistically analysed by the usual techniques. The mean percentage germinations for each treatment are given in *Table 6*. Examination

Table 6. Percentage germination of seed after 21 days

Treatment*						
C.	*S.A.*	*S.A. + P.*	*S.A. + L.*	*M.A.P.*	*C.C.*	*U.*
97·3	66·3	81·6	90·3	92·6	93·3	86·0

* For key to column headings, see text.

of the significant comparisons substantially confirms the conclusions drawn from examination of the curves. Thus urea is more effective in encouraging germination than sulphate of ammonia

[t, S.A. versus U. = 2·80 (with 12 D.F.) significant at $P = 0{\cdot}02$]

while the effect of urea versus control is only significant at $P = 0{\cdot}1$.

[t, C. versus U. = 2·105 (12 D.F.)]

Neither calcium-containing treatment differs significantly from the control in percentage germination. On the other hand the two treatments containing both phosphorus and ammonia (S.A. + P. and M.A.P.) have different results on germination. The mono-ammonium phosphate treatment has no effect, while sulphate of ammonia with double superphosphate gives a significantly reduced germination.

[t, C. versus (S.A. + P.) = 2·55 (12 D.F.) significant at $P = 0{\cdot}05$]

The differences between the various phosphate-containing fertilizers may be due either to the effect of the acidity of the ammonium sulphate,

Table 7. Mean increase in pH of soil

Treatment	*C.*	*S.A.*	*S.A. + P.*	*S.A. + L.*	*M.A.P.*	*C.C.*	*U.*
After 10 days	0·63	0·13	0·26	0·92	0·70	1·00	1·13
After 20 days	0·36	0·20	0·05	1·06	0·02	1·03	0·33

M.S.D. (10 days) P: 5 per cent. = 0·61.

or to the lower solubility of the phosphate added to the sulphate of ammonia, compared with the phosphate in the mono-ammonium phosphate. Since the calcium-containing fertilizers are both effective in ensuring full germination, it can be assumed that the reduced germination is due to the acidity of the compound used. The pH changes (*Table 7*) substantiate this, although

it is apparent that the pH change after 10 days is more comparable to the percentage germination. This is understandable as the maximum percentage germination was attained in all treatments within ten days. Subsequent changes in pH cannot therefore have influenced percentage germination, and may well have been brought about by the growth of the young seedlings.

The pH changes which have taken place in the calcium-containing treatments (S.A. + L.; C.C.) and the control (C.) in 10 days, may also be associated with a decrease in the value of the oxidation reduction* potentials of the soil. For WILLIS (1932) by adding lime to soils has shown pH and E_h to be inversely related; when the pH increases by one unit the oxidation reduction potential decreases by 58 mV. Changes in oxidation reduction potential may be of some importance in the germination of seed.

Viability of seedlings

In the previous experiment it was not possible to determine the exact effect of fertilizer on the viability of seedlings owing to the low percentage germination in the treatments containing fertilizers [*Tables 4* and *5* (a)].

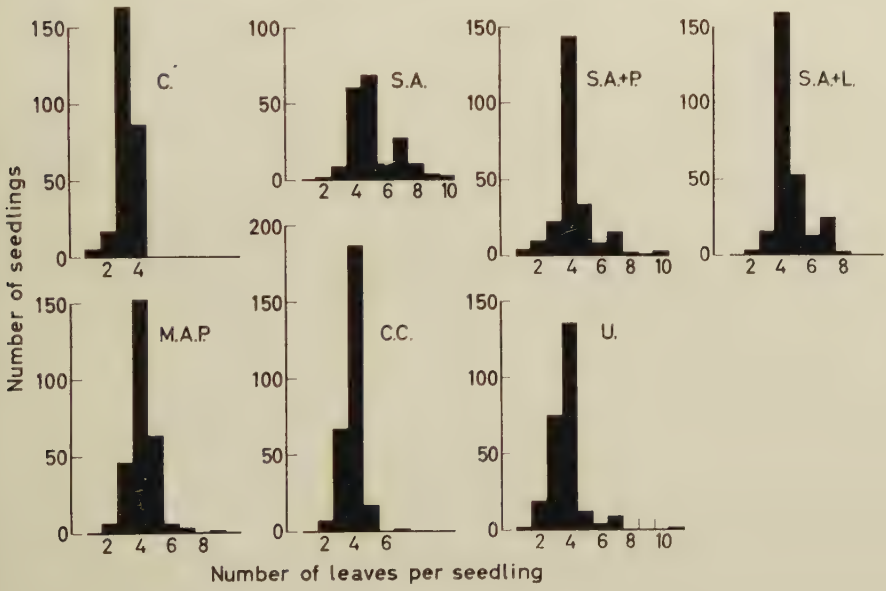

Figure 4. Relation between number of seedlings, number of leaves per seedling and fertilizer treatments. Treatments as in Figure 3 and text

In this next experiment, by supplying running water which had been previously shown to reduce the effect of fertilizer, it was possible to ensure high germination in all fertilizer treatments, and thus to follow the effect of fertilizers on subsequent growth of the seedlings.

The record of leaf counts made for seedlings in each treatment is given in *Figure 4*. Many more seedlings with high leaf numbers were recorded in this

*The terms 'reduction–oxidation', 'oxidation–reduction' and 'redox' are used interchangeably in this paper.

experiment than were found in the previous factorial experiment (*Figure 2*), although the unfertilized control (a_0, b_0, c_0) in that experiment shows a leaf distribution similar to that for the control (C., *Figure 4*) in this experiment. The record of the number of seedlings with one or more tillers given in *Table 8*, shows, as clearly as *Figure 4*, that the fertilizer has a considerable effect on growth and uniformity of the seedlings. The great lack of uniformity is found in treatments receiving sulphate of ammonia (S.A.; S.A.+P.; S.A.+L.), where the seedlings range from those with one leaf to those with 10 leaves and where many of the seedlings also have one or more tillers. From the practical viewpoint it is disadvantageous to have such a lack of

Table 8. Total number of seedlings with one or more tillers

Number of tillers	*Treatment*						
	C.	*S.A.*	*S.A. + P.*	*S.A. + L.*	*M.A.P.*	*C.C.*	*U.*
1	0	42	25	42	10	2	19
2	0	19	6	2	1	0	0
3	0	1	1	0	0	0	1

uniformity in seedlings. The cause is obviously due to the initial rapid germination of some seeds followed by the slow germination of the remainder, and to the high solubility of the sulphate of ammonia in these treatments, which would mean that the first germinated seeds would make use of the fertilizer very rapidly. The addition of lime to the sulphate of

Table 9. Total leaf colour score

Treatments scored from 1 (light green) to 7 (dark green) by three independent observers. The scores from each replicate and each observer were added to give the total score.

Treatment						
C.	*S.A.*	*S.A. + P.*	*S.A. + L.*	*M.A.P.*	*C.C.*	*U.*
17	55	56	57	53	38	45

M.S.D. ($P = 0{\cdot}01$) = $\pm$ 1·05.

Table 10. Mean fresh weight (mg) of seedlings after 21 days

Treatment						
C.	*S.A.*	*S.A. + P.*	*S.A. + L.*	*M.A.P.*	*C.C.*	*U.*
281·3	929·6	704·0	748·0	632·3	479·3	472·6

ammonia slightly reduces the wide variations in seedling size (as expressed by leaf number) possibly by rendering the ammonium sulphate less soluble. In the remaining treatments, which do not contain ammonium sulphate, there is far less variation in the size of the seedlings (*Figure 4*), and fewer seedlings have tillers (*Table 8*).

The variations in viability of the seed shown here seem to be related to the uneven but rapid growth of the seedlings after germination. The heaviest seedlings were found in ammonium-containing treatments (*Table 10*),

as were the greenest seedlings (*Table 9*). It is apparent that the viability of the seedlings is not related to the germination percentage, but rather to a combination of germination rate and subsequent growth rate. Neither is there any apparent relationship between pH change and uniformity of seedlings, although there are fewer seedlings with tillers where there has been an increase in pH during the first 10 days of growth. In two cases where the pH has subsequently decreased between 10 and 20 days (M.A.P., U.), there are a few seedlings with tillers, but far fewer than in sulphate of ammonia treatments, where there has been very little change of pH during the second 10 days.

It would seem possible that tillering is delayed by increasing pH, and that a decrease in pH enables tillers to form. This conclusion would appear sound, were it not that the addition of lime to sulphate of ammonia (S.A. + L.), whilst increasing pH, does not inhibit tillering. However, in this last treatment the solubility of the sulphate of ammonia may be sufficiently affected to offset the effects of pH changes.

Effect of fertilizers on yield of seedlings

The average fresh weight yield per seedling at the end of the experiment is shown in *Table 10*. The original data were analysed statistically, and a number of statistical comparisons made. The effect of fertilizers on the yield of the seedlings is independent of their effect on germination, but closely related to the colour of the seedlings (*Table 9*). The significant yield comparisons were:

Sulphate of ammonia versus urea

[t, (S.A. versus U.) $=6{\cdot}293$ significant at $P=0{\cdot}001$]

phosphorus-containing versus control

[t, (S.A.+P.)+M.A.P. versus C. $=6{\cdot}152$ significant at $P=0{\cdot}001$]

and calcium cyanamide versus sulphate of ammonia+lime

[t, (S.A.+L.) versus C.C. $=3{\cdot}699$ significant at $P=0{\cdot}01$]

All the comparisons have 12 degrees of freedom. As the amount of nitrogen was the same in all treatments except the control, increases in yields over the control must be due to differences in the availability of the nitrogen in the different compounds. The presence of lime or phosphates in the fertilizer would appear to have affected yield most in the least soluble compounds (M.A.P.; C.C.). Similarly sulphate of ammonia alone is much better than urea for promoting growth.

It must be remembered that for practical purposes the green heavy seedlings obtained from sulphate of ammonia treatments may be of disadvantage on transplanting the rice, for as well as there being fewer of them, they are softer and more liable to damage.

DISCUSSION

Does a low oxygen content inhibit rice seed germination in soil ?

The rice plant differs from all other cereals by being able to grow under swamp conditions. In dryland plants seed germination is in general inhibited or retarded by wet conditions (see for example HARPER and LANDRAGIN, 1955) and low oxygen pressures (SHULL, 1911). Rice on the other hand has been shown by NAGAI (1916) and JONES (1933) to germinate

under water, and by BARTON (1952), TAYLOR (1942) and VLAMIS and DAVIS (1943) to germinate in almost anaerobic conditions, although contrary to these results SIRCAR, DAS and LAHRI (1955) have shown that growth of the rice embryo is affected by the presence of water. Only JONES (1933) carried out his experiments on soil, and although the wet conditions he used allowed the rice to germinate he obtained much lower germination percentages than were obtained in the laboratory experiments of Taylor and Vlamis and Davis. Barton's results suggest a possible explanation for the differences in germination in soil and laboratory conditions for she found that although carbon dioxide did not reduce germination of rice seed appreciably, it did cause considerable delay in germination. Thus in soil where the anaerobic conditions may well be due to accumulation of carbon dioxide, the seed would behave differently from germination tests under laboratory conditions where the anaerobic atmosphere was obtained with nitrogen.

The seeds of other marsh plants have been found (EDWARDS, 1933; NAGAI, 1916) to germinate under anaerobic conditions; although MORINAGA (1926a) has shown that seeds of *Typha latifolia* will not germinate under water or in complete absence of oxygen but will germinate when oxygen percentages are very low. From these results we can conclude that, while it is not conclusive that rice and other marsh plants will germinate under completely anaerobic conditions, it is reasonably certain that they will germinate when the amount of oxygen present in the germinating medium is very small.

In our experiments we have used a number of soil and fertilizer treatments which have probably brought about differences between treatments in the availability of oxygen. Thus in some treatments we have used ammonium sulphate as a nutrient, and PANABOKKE (1953) has shown that the use of ammonium nitrogen as a fertilizer will decrease the oxidation–reduction potential (E_h) of the soil, whilst PEARSALL (1938) has shown that in waterlogged soils a decrease in E_h (oxidation–reduction potential related to hydrogen electrode) is generally accompanied by an increase in the proportion of water, and hence a decrease in the amount of air in the soil. The ammonium sulphate treatments we have used can also be considered to have reduced the amount of air, and therefore oxygen, present in the soil.

In our experiments, besides fertilizer treatments we have also used a number of water treatments (c_0, c_1 and c_2) which can be considered to supply different amounts of oxygen at the soil surface, for PONNAMPERUMA (1955) has shown that submergence lowers the oxidation–reduction potential of the soil. Thus the stagnant water treatments (c_1) would probably have less oxygen than either the moist soil surface treatment (c_0) or the running water treatment, which is apparently confirmed by the percentage germinations obtained (*Tables 4* and *5*). The results obtained in the test of technique (*Table 2*) also provide confirmatory evidence. Those treatments with ammonium fertilizer (b_1) would have less oxygen that those without (b_0) and those with seeds buried (a_1) less oxygen than those with the seed uncovered (a_0). That there has been a reduction in percentage germination due to fertilizers is shown in *Tables 6* and *11*. The amount of germination decrease due to fertilizer is affected both by the water treatments (c_0, c_1, c_2)

and by the seed covering treatments (a_0, a_1), the decrease being greater where stagnant water and seed covering is used (a_1, b_1, c_1). In the same factorial experiment reduction of germination due to fertilizer is least in the running water treatment (*Table 11*); this may be due either to the leaching away of the fertilizer, or to the supply of oxygen by the running water. Similarly the decrease due to fertilizer is lower in the no surface water treatment (c_0), where air would be present at the soil surface, than in the stagnant water treatment. These results suggest that there is a balance between the state of reduction of the soil or fertilizer and the actual oxygen present. In treatments where air is supplied continuously to the soil surface, either direct (c_0) or in water (c_2), there is less lowering of percentage germination, presumably because the redox reactions of the fertilizers and soil are unable to go to completion as conditions are not fully anaerobic.

Table 11. Decrease in percentage germination due to fertilizer
Data from *Table 5* (a)

Treatments	*No surface water*	*Stagnant water*	*Running water*
Seed uncovered	50·5	76·0	11·5
Seed covered	73·5	86·0	56·5
Mean reduction	62·0	81·0	34·0

If we consider the results of the fertilizer experiments, we find that, although the fertilizer treatments containing ammonium sulphate again cause a decrease in germination (*Table 6*), other fertilizers do not lower germination to the same extent. Since in this experiment running water was supplied and the seeds were uncovered, the reduction in germination is probably not due to a decrease in available oxygen. The percentage germination of the control (C.) is as high as in the corresponding treatment (a_0, b_0, c_0) in the factorial experiment. Thus reductions in germination percentage must be due either to the effect of the fertilizer on the oxidation–reduction status of the soil, or to some other cause. If we assume that other causes of reduced germination are negligible, we can assume that the decrease in percentage germination due to ammonium sulphate alone (S.A.) is caused entirely by a decrease in oxidation–reduction potential as outlined by Panabokke (1953). Similarly the increases in germination due to the addition of phosphate or lime, or by changing the fertilizer used, may well be due to changes in the redox system. This explanation, although suggestive, has not been verified and the results can be explained better as due to other causes.

It should also be remembered that once the seed has germinated, the supply of oxygen is of less importance, as it is known (Alberda, 1953) that oxygen can be transferred from the stem to the roots of a rice plant.

Effect of different nitrogen fertilizers apart from their action due to possible oxidation–reduction changes

The germination of seed in ammonium sulphate (S.A.) alone is much lower than in either ammonium sulphate plus double superphosphate

(S.A.+P.) or mono-ammonium phosphate (M.A.P.), both of the latter containing ammonia. Phosphate compounds are often added to the seed-bed during rice seed germination (BUTLER, 1914; GRIST, 1953; SETHI *et al.*, 1952) although under field conditions the advantage is not apparent. It is, however, obvious that phosphate encourages early growth of the seedling, possibly by encouraging rooting and thus enabling more efficient utilization of the ammonium-containing parts of the fertilizer by the plant. Workers in Indonesia claim that the seed treatment with phosphate gives a marked temporary increase in vigour (IGNATIEFF, 1951), but similar work in India showed that soaking it in phosphate solutions reduced the germination of the seed (IGNATIEFF, 1951). In our results, however, the most vigorous seedlings were found in all ammonium-containing treatments (*Table 9*), whether phosphate was present or not, and the greatest reduction in germination in ammonium sulphate alone (S.A.). If the addition of phosphate to an ammonium fertilizer is not the cause of increased germination, and it appears there are two views on this, then ammonium sulphate (S.A.) on its own must be assumed to be toxic to germination. This may well be so, for AMEMIYA, AKEMINE and TORIYAMA (1956) have shown that ammonium sulphate solution inhibits the germination of rice embryos. This result is not, however, confirmed in practice (GRIST, 1953) for ammonium sulphate is used extensively on seed-beds without any adverse effect. Our experiments have shown that the adverse effects of ammonium–containing fertilizers can be reduced in a number of different ways (running water, addition of lime, addition of phosphate) all of which would seem to furnish a different explanation for their effectiveness. The effect of the calcium-containing fertilizers could, for example, be explained by assuming that they neutralize the acidity caused by the ammonia. From the contradictory results given in the literature, it is apparent that further investigation into the effect of ammonium sulphate on germination is needed, although it remains possible that the toxic agent is ammonia gas, which is released when no other substance is present to react with it. The reduction in germination due to urea (U., *Table 9*) could be explained on the basis of the release of free ammonia.

Other environmental factors influencing rice seed germination

We have shown that most of the reduced germination in our experiments can be explained on the basis of the free oxygen and the oxidation–reduction potentials of the soil, or the effect of toxic agents, but there may be other causes of low germination.

Temperature differences can be eliminated as a likely cause, for the daily soil temperature records taken in the factorial experiment (*Table 12*) show no significant variation between treatments. The activity of pathogens can also be rejected, as the preliminary experiment showed them to be absent or not effective in the soil used in these experiments.

Many workers have studied the effect of light on various seeds and have found that the effect varies with the type of light supplied. Infra-red light is said to inhibit germination in lettuce (BORTHWICK *et al.*, 1954; EVENARI and NEUMANN, 1953). The quantity of light is also important in the germination of seed; for example, *Betula pubescens* (BLACK and WAREING, 1954)

will not germinate in the dark. Of the conditions used in our experiments, seeds planted below the surface are in the dark, and seeds planted on the surface with no water would be receiving more infra-red radiation than those in stagnant or running water, as water is a strong absorber of infra-red radiation. The results obtained show that for seed sown without fertilizer

Table 12. Mean soil temperatures (°F)

Treatments	*No surface water*	*Stagnant water*	*Running water*
Seed uncovered; no fertilizer	83·0	81·5	81·5
Seed covered; no fertilizer	79·5	81·0	82·5
Seed uncovered; fertilizer	80·5	82·0	82·0
Seed covered; fertilizer	79·0	80·5	81·0

(a_0, b_0) germination on the soil surface is nearly the same for all water treatments, thus suggesting that infra-red radiation is not a factor in inhibiting the germination of rice seed. However, all the seeds planted below the soil surface show a decrease in percentage germination from the corresponding treatment on the soil surface (see *Table 13* and *Figure 1*). The analysis of variance (*Table 5*) has shown that the effect of covering the seed is highly significant. *Table 13* shows, however, that the decrease is not uniform; if the decrease was due entirely to light, a uniform reduction in germination would have been expected. This confirms the conclusions of Akemine (cited in COPELAND, 1924) who stated that light did not affect rice seed germination.

The absolute pH at 10 days of the soil in the fertilizer experiment is unlikely to have affected germination since the values for pH in all the treatments lie between the optimum pH limits for growth given by ROLA and GALPEZ (1949).

Table 13. Decrease in percentage germination due to covering seed
Data from *Table 5* (a)

Treatments	*No surface water*	*Stagnant water*	*Running water*
Without fertilizer	20·5	6·0	8·5
With fertilizer	43·5	16·0	53·5
Mean decrease	32·0	11·0	31·0

Death and viability of germinated seed

We have so far only considered the final percentage germinations obtained, and not the form of the germination curves. The most interesting features in these curves are shown in those treatments which have a maximum

germination higher than the final germination. The curves for covered seed without fertilizer (a_1, b_0) and fertilizer only (a_0, b_1) in the stagnant water treatment (c_1), and for sulphate of ammonia (S.A.) in *Figure 3*, show such a reduction. It has already been suggested that conditions favourable to the development of a low oxidation–reduction potential, and low oxygen may result in delayed germination of the seed. It has also been shown (PANABOKKE, 1953) that root growth in rice is inhibited by low oxygen, which delays growth sufficiently for toxic gases (ammonia or carbon dioxide) to form before some of the seedlings are sufficiently developed to survive adverse conditions. Seeds which germinate rapidly would escape the effects of gas accumulation or low oxygen, as it can be assumed that the breakdown of chemicals containing or producing ammonium would not be immediate, nor would be the accumulation of carbon dioxide. Comparison of the pH increases (*Table 7*) at 10 and at 20 days indicates that the breakdown of ammonium compounds in nitrate is slow, as in 10 days all fertilizers containing or producing ammonium (S.A., S.A.+P., M.A.P., U.) increased the pH indicating the formation of alkaline ammonia, followed by a decrease in pH which indicated the formation of nitrate in the soil; only treatments containing lime remained with a high pH.

Consideration must also be given to the viability of the seedlings under various conditions. Any visible effect of toxic gases (ammonia or carbon dioxide) or a lack of oxygen would be less for seedlings than for seeds; seedlings would only have roots in the soil and it is known (ALBERDA, 1953) that air can move through the rice plant to the roots. The differences in growth shown by the numbers of leaves on each seedling could have been caused by an inhibition of growth before the seedlings were large enough to utilize normal air. The data given in *Table 3* show that seeds sown below the soil surface have fewer leaves than those sown on the surface, which is explained by assuming that the seeds below the surface are later in starting to grow than those planted on the surface. Again in the factorial experiment (*Figure 2*) seedlings receiving fertilizer have more leaves than those not receiving it. In the fertilizer experiment (*Figure 4*) where the amount of nitrogen supplied in all treatments except the control was equal, there are differences in the distribution of leaf number according to the fertilizer supplied as well as differences in the fresh weight yield of seedlings (*Table 10*). Differences between unfertilized seedlings and fertilized seedlings in all experiments would appear to be due to a combination of delay in germination with the solubility, and hence availability, of the fertilizer supplied, as from the evidence presented the further growth of the seedlings would appear to be independent of the germination of the seedlings.

CONCLUSIONS

From the results presented here it is obvious that rice seed is sensitive to a variety of soil conditions, and that germination is best when the seed is well aerated, although it will take place under anaerobic conditions. The addition of fertilizers to the soil just prior to sowing causes a large reduction in germination when water conditions are adverse (i.e. when no surface water is present, or seeds are covered with standing water). The presence of ammonium sulphate reduces germination considerably, and causes seedlings

to have a wide variation in size. The ammonium sulphate does, however, produce the heaviest seedlings. The adverse effects of ammonium sulphate can be mitigated to some extent by the addition of lime or superphosphate with the ammonium sulphate, although even in these conditions the seedlings are not uniform. Greatest uniformity of seedlings is obtained when calcium cyanamide is used as a fertilizer, although here the weight of seedlings is about half that obtained with sulphate of ammonia, but it is twice that obtained without fertilization. How some of the nitrogen fertilizers used would behave under water conditions other than running water is not known and requires further investigation. It is also necessary to investigate further the toxic effects of ammonium sulphate, as its widespread use in commercial rice production does not seem to take cognizance of its effect on germination of the seed, which may be due both to the production of free ammonia and also to the lowering of oxidation–reduction potentials in the soil when it is used. That oxidation–reduction potentials of the soil are important in the later stages of growth in rice has been shown by PONNAMPERUMA (1955); they may be equally important in the germination and early growth of the plant.

SUMMARY

Experiments with the germination of rice seed on soil have shown that the seed is sensitive to a variety of water, soil and fertilizer treatments. Germination is markedly reduced by covering the seed, stagnant water, and ammonium fertilizers. The decrease in germination under such adverse conditions can be ascribed to a combination of the oxygen content and oxidation–reduction potential of the soil, or to the accumulation of toxic gases. Further investigation is, however, needed to explain fully the responses of the seed obtained in the experiments described. Observations on the viability of seedlings after germination show the effects of treatment on seedling growth to be independent of the effect on germination.

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The Control of Cacao Swollen Shoot Disease in Nigeria

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Swollen shoot disease was first discovered in Nigeria in 1944, during the first survey of the cacao-growing areas in the Western Region, where it is now known to be widespread in Ibadan and Abeokuta Provinces. The removal of infected trees was the only possible method of control (Thresh, 1958a) and between January 1946 and June 1950 one and a half million infected trees were destroyed by the Department of Agriculture in an unsuccessful attempt to eradicate the disease completely. It was then realized that this would be costly, difficult and unpopular, and control measures were abandoned in heavily infected parts of Ibadan and Abeokuta Provinces in 1950 and 1953. Elsewhere the cacao has been inspected regularly and new outbreaks treated immediately. This policy achieved limited success in restricting the build-up of virus in the cacao outside the abandoned areas, but increasing difficulty is being experienced in maintaining the situation, and the number of infected trees which were found and cut out increased from 476 in 1950 to 12 403 in 1956.

A review of the history and control of cacao swollen shoot disease in Nigeria was presented by Lister and Thresh (1957a). The present paper discusses certain aspects of this work in detail and is based on observations by the survey parties responsible for the routine eradication control measures and by the staff of the Nigerian Substation of the West African Cocoa Research Institute.

THE AREAS OF MASS INFECTION

The present situation in the areas of mass infection

The abandoned areas of mass infection contain some of the best available cacao soils in the Western Region and involve approximately half the 225 000 acres of mature cacao in Ibadan Province, and approximately 17 000 of the 120 000 acres in Abeokuta Province. Thus virus is spreading unchecked in almost one seventh of the 989 000 acres of cacao recorded in the Western Region and the decision to abandon first one and then a second major growing area was a significant one which has influenced developments in the areas of mass infection and outside them.

When the two areas of mass infection were abandoned they contained a large number of infected trees, but there had been no detailed assessment of the extent of infection. However, at least 30 per cent of the trees were infected in densely planted areas east of Ibadan and numerous scattered outbreaks occurred elsewhere. Similarly, in the Ilaro area of Abeokuta Province the cacao around half the 104 villages contained diseased trees in 1953 and at

least 300 acres of mature cacao was infected. Observations made on naturally occurring outbreaks in Ibadan and Abeokuta Provinces give some indication of the recent rate of virus spread (THRESH, 1958b). Moreover, infection has become increasingly obvious to members of the survey staff traversing the cacao areas around Ilaro and Ibadan, where infection is now widespread. Indeed, HADLAND (unpublished information) has recently suggested that at least 5 000 000 trees are infected in Ibadan Province alone.

Significance of areas of mass infection

Inadequate information on the incidence of infection in Ibadan and Abeokuta Provinces and on the effect of virus on yield make it impossible to estimate the loss in crop caused by cacao viruses. Moreover, the amount of cacao handled annually by the grading stations gives only an approximate indication of production trends, as the internal movement of cacao varies between years. However, yields are apparently declining in the Ibadan area of mass infection, although they are increasing elsewhere in the province (HADLAND, unpublished information). Furthermore, yield records taken at selected sites indicate that the effect of virus depends on the growing conditions and on the length of time the trees have been infected (LISTER and THRESH, 1957b).

Clearly swollen shoot disease is an important factor reducing yields and the loss in crop increases annually, as more trees become infected and deteriorate. Precise experiments are now in progress to determine the effect of a range of Nigerian viruses on yield and the information obtained, together with the results of a proposed survey of the areas of mass infection, should eventually facilitate a more definite estimate of crop losses.

A further consequence of the uninterrupted spread of virus in the abandoned areas is that these are becoming increasingly dangerous foci of infection, which is spreading to the surrounding cacao. The precise significance of the abandoned areas is difficult to evaluate as naturally infected wild hosts may act as additional virus sources (THRESH, 1958b). Nevertheless, the movement of windborne mealybugs from the abandoned cacao probably accounts for the occurrence of many of the new outbreaks now being found elsewhere (LISTER and THRESH, 1957a). Consequently it is hardly surprising that the cutting-out parties are experiencing difficulty in restricting the spread of swollen shoot disease and that the number of newly discovered outbreaks has increased almost every year since 1947. This indicates that increasing difficulty will be experienced in the future, particularly as there is no practical method of checking the movement of windborne mealybugs which may be carried over large distances and probably for miles (STRICKLAND, 1950; CORNWELL, 1955).

Policy of the Department of Agriculture in areas of mass infection

The policy of the Department of Agriculture in the areas of mass infection has been to encourage the growing of crops other than cacao. Cacao seedlings are not available to farmers for planting within these areas and most of the trees cut out before 1950 are being replaced by citrus or oil palms. However, numerous small plots of cacao have been established by the farmers on their own initiative. These plots are frequently near infected trees and this un-

controlled replanting maintains the infection cycle. Consequently plans are being made by the Department of Agriculture for the rehabilitation of the cacao on more orderly lines and the best available planting material will be used on selected soils and brought under regular inspection. Obviously it would also be advantageous to plant the largest possible blocks and to remove all infected cacao trees and possible wild hosts of cacao viruses from within and around the farms. Under these conditions losses caused by swollen shoot disease are likely to be small (BENSTEAD, 1951 and 1953; THRESH, 1958b).

The best cacao immediately available for planting in the areas of mass infection will be from selected Amelonado or Amazon types. However, resistant or tolerant material may eventually be introduced. Alternatively, planting material may be protected from the effects of severe virus by mild strains. These possibilities and the use of barrier crops and insecticides for controlling the mealybug vectors of swollen shoot disease are being investigated by the W.A.C.R.I. (THRESH, 1958a), and the chances of successfully rehabilitating cacao in the areas of mass infection will probably be increased and the present downward trend in production reversed. Any reduction in the extent of the abandoned areas will increase the likelihood of controlling virus spread. Moreover, cutting out followed by replanting provides an opportunity of changing the present cultivation system, and yields per acre may be increased above their present unsatisfactory level.

DISCOVERY OF NEW OUTBREAKS

Large acreages of infected cacao are likely to remain in the areas of mass infection for some years and it will be essential to maintain a regular survey of the remaining cacao areas and to eradicate any outbreaks of virus found. Thus the amount of virus spread will largely depend on the efficiency with which new outbreaks are detected.

At present the only practical method of detecting field infections is by routine inspection for symptoms. Chemical methods of diagnosis have been evolved (HANCOCK, 1949; TINSLEY and USHER, 1954) but are not suitable for extensive use. Consequently the discovery of new outbreaks depends on the routine survey staff, who must detect trees with symptoms by inspection from ground level. Cacao in localities adjacent to the areas of mass infection is inspected every six months and the more remote cacao every year. These inspections are carried out by 20 to 22 Field Overseers under a headman and supervised by the Provincial Agricultural Officer. Inspection parties are based at the major cacao towns and villages and each party examines approximately 160 acres of cacao each working day. The annual cost of the inspection service is £170 000 and eight survey groups are in operation in Ibadan Province alone.

At the outset of the survey work the cacao buying stations were known, but there was little information on the distribution of the growing areas. These were often in remote or difficult country and the survey parties were greatly hampered by the lack of maps and access roads (HADLAND, 1951). Furthermore, virus symptoms are not always easy to find on infected trees. For example at Koroboto up to 10 per cent of the known infections may be symptomless when examined (THRESH, 1958c). Symptoms tend to be

inconspicuous during the dry season, when branches defoliate and swellings are destroyed by capsid attack or dieback. Similarly, symptoms are also difficult to find during the cool cloudy conditions in the rains, when trees grow slowly. These seasonal variations influence the efficiency of the routine surveys and partly explain why most new outbreaks are found at the beginning and end of the rains, when the trees grow vigorously and show conspicuous symptoms. Moreover, the likelihood of finding outbreaks is at a minimum in areas receiving their annual inspection during the dry season or at the height of the rains.

Thus it is hardly surprising that many outbreaks are missed by the survey parties for years until they involve more than 100 infected trees (Lister and Thresh, 1957a). However, the survey parties have been working since 1946 and they should have gradually increased in efficiency, particularly as the cacao areas are now known and maps are available. There is no indication of this and each of the 65 new outbreaks found between 1954 and 1956, contained an average of 186 trees, compared with an average of 108 infected trees found in each of the 61 outbreaks discovered between 1947 and 1953 (*Figure 1*).

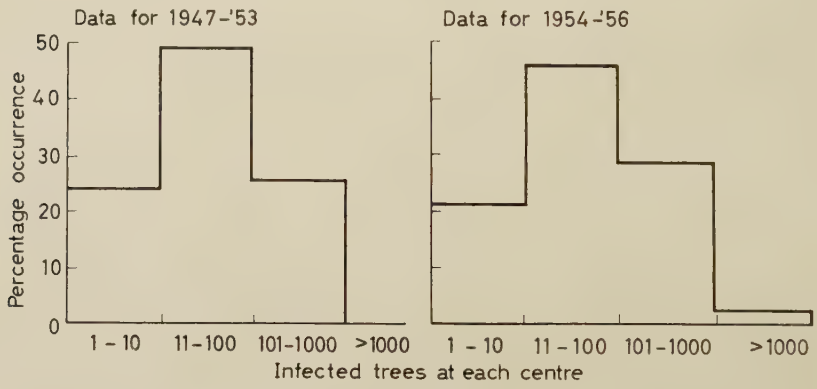

Figure 1. Frequency distribution of number of infected trees originally found at 61 new centres of infection discovered 1947–53 and at 65 centres discovered 1954–56

Ideally, outbreaks should be detected at an early stage when they can be eradicated easily and before they have become important secondary foci of infection. This has been achieved on a small scale (Posnette, 1943), although a similar inspection service operating throughout Nigerian cacao would be prohibitively expensive. Nevertheless, efforts are being made by the Department of Agriculture to increase the efficiency of the survey. Each member of the survey staff will in future be allocated an area of cacao, to examine for virus symptoms every six months. The work will be checked at irregular intervals by two specially supervised survey groups and some increase in efficiency is expected, particularly as more detailed maps are being prepared, using aerial photographs.

TREATMENT OF OUTBREAKS ON DISCOVERY

Eradication measures against swollen shoot disease have changed twice since 1946. At the outset only obviously infected trees were removed, but

the routine measures were then changed and between 1950 and 1955 the apparently healthy trees occurring within 30 yards of each treated outbreak were cut out as well. Recently a coppicing technique has been used to evolve a more rational eradication policy. The coppicing work also facilitated an assessment of the efficiency of the earlier measures.

Difficulties experienced in attempts to control swollen shoot disease by eradication methods

A cutting-out policy involving only the removal of obviously infected trees is usually an inefficient method of eradicating virus outbreaks (POSNETTE, 1943; ANON., 1945). For example in the recent Nigerian coppicing experiments, removing obviously infected trees would have controlled 18 of the 32 outbreaks which contained less than six obviously infected trees, but only one of the 48 larger outbreaks (*Table 1*). Removing the apparently healthy ' contact ' trees would have controlled 12 of the 16 outbreaks containing less than six obviously infected trees and 16 of the 46 larger ones.

Table 1. Comparative efficiency of two cutting-out treatments for eradication of outbreaks of cacao swollen shoot virus

Size of outbreak (No. of infected trees)	*No contacts cut**		*Immediate contacts cut**	
	Outbreaks eradicated†	*% eradicated*	*Outbreaks eradicated†*	*% eradicated*
>50	0/17	0·0	2/20	10·0
11–50	1/19	5·3	10/19	52·6
6–10	0/12	0·0	4/7	57·1
1– 5	18/32	56·2	12/16	75·0
Total ..	19/80	23·7	28/62	45·2

*In addition to the trees found with symptoms by a routine inspection of the standing trees from ground level.
†The fraction indicates the number of outbreaks successfully eradicated out of the total number treated.

The frequent failure of simple cutting-out measures is due to the inability of the survey parties to detect the latent and almost symptomless infections. One method of dealing with these missed infections is to cut them out as they are found with symptoms when treated outbreaks are reinspected. This was the practice adopted at first in Nigeria and is still used in Ghana (HAMMOND, 1957). However, it is time-consuming and inconvenient for the survey parties to keep on returning to the sites of treated outbreaks. Moreover, the method is fundamentally inefficient as virus may spread from the latent and missed infections in the interval between the initial treatment and subsequent ones. Indeed, latent infections may be particularly dangerous sources of virus, as they often support higher mealybug populations than severely affected trees and mealybugs may move from deteriorating trees (CORNWELL, 1956).

The infected trees which remain after an eradication treatment are of several types, viz.:

(*1*) Trees with symptoms which are difficult to spot
(*2*) Recently infected symptomless trees

(*3*) Virtually symptomless trees infected with very mild strains of virus

(*4*) Tolerant trees with inconspicuous symptoms.

Trees in the first category were detected by experienced spotters climbing into the canopy or by examining the branches and foliage when apparently healthy trees were felled. Tolerant trees were discovered by transmitting severe virus from infected trees with consistently mild symptoms. The remaining trees were detected by cutting them back to ground level and keeping the regeneration growth under regular inspection. Infected trees usually produce shoots with conspicuous symptoms and this coppicing technique is probably the most crucial of the available tests for demonstrating virus.

The relative distribution of latent and missed infections into the four categories has not been investigated in detail, but at Koroboto less than 10 per cent of all the infected trees were tolerant or infected with mild viruses. However, the distribution probably varies widely between outbreaks and seasons. Thus at three outbreaks found in Ibadan Province in 1954 and 1955 (*Table 2*), there was wide variation in the ratio of the number of infected trees detected before felling, to the number found subsequently. There was also considerable variation in the ratio of missed to latent infections and the greatest proportion of missed trees was at Adifa, where the farms were badly damaged by capsid attack and dieback and showed conspicuous symptoms of iron and nitrogen deficiency; additional evidence that virus symptoms are often inconspicuous on moribund trees.

Table 2. Results of experiments in Nigeria in coppicing outbreaks of cacao swollen shoot virus

Virus outbreak	*Total number of apparently healthy trees coppiced*	*No. of infections*		
		*Observed before felling**	*Additional revealed on felling†*	*Additional revealed by coppicing‡*
Ina Farm	274	20	4	7
Alagbe	764	70	11	6
Adifa	998	25	14	9

*By a routine inspection of the standing trees.
†By a thorough inspection of suspected trees at ground level.
‡By a regular inspection of the growth made after coppicing all the trees on which no symptom could be found.

Treatment of virus outbreaks between 1950 and 1955

Few outbreaks were expected to appear outside the areas of mass infection. Nevertheless, to increase the chances of eradicating any outbreaks of virus which did occur, the obviously infected trees were removed and also the adjacent apparently healthy trees occurring within 30 yards. There was some justification for cutting out the apparently healthy trees in contact with those found with symptoms (Posnette, 1943; Anon., 1945) and the recent coppicing experiments have confirmed this, but there was no evidence to warrant such drastic measures. However, the 30-yard treatments were continued, even though an increasing number of outbreaks were being found annually and the original intention of reducing the areas of mass infection was abandoned.

Between July 1950 and December 1955, virus outbreaks were found in the cacao around 98 villages and 114 341 trees were cut out in attempts to control outbreaks involving 10 087 obviously infected trees. The cacao to a distance of 200 yards around the cut-out areas was subsequently inspected every three months and the remaining cacao every six. A further 6 006 infected trees were found during these re-inspections and cut out, together with the adjacent apparently healthy trees occurring within 30 yards.

The Department of Agriculture records for treatments outside the areas of mass infection are compiled on a village basis and no attempt is made to keep separate records for individual outbreaks. Thus the first treatment in the cacao around a village is referred to as the initial one and all subsequent cut-outs are referred to as re-treatments, irrespective of the date on which they are done. This simple and convenient system has been used consistently since 1950. Nevertheless, it is misleading and implies that all the infected trees found in the cacao around a village belong to the same outbreak. This is not always true and a treatment may be recorded as a re-treatment, although it involves a completely new outbreak found many months after the original one and some distance from it. Thus the ratio of 1:1·7 between the number of infected trees cut out during the re-treatment of outbreaks, compared with the number removed at the outset, is unexpectedly high and similar to the value of 1:2·1 recorded in Ghana, where only obviously infected trees were cut out until 1957 (HAMMOND, 1957). However, it does not follow that the Ghana and Nigerian treatments are equally efficient, as the ratios are not strictly comparable and cutting-out treatments in Ghana are only referred to as re-treatments if they are within 30 yards of a treated outbreak.

The number of villages where outbreaks were found for the first time is increasing annually (*Table 3*), although the build-up is remarkably slow in relation to the extent of the abandoned areas and the spread of viruses such as sugar beet yellows, which may infect virtually the whole root crop in the British Isles in a single season. Clearly swollen shoot is a ' crowd ' disease of the type defined by VAN DER PLANK (1948) as one which does not spread far in considerable amount.

Table 3. The number of swollen shoot centres where eradication measures have been applied each year since 1950 and the control achieved

Year of initial treatment	*Centres eradicated by initial and re-treatments**						*Centres definitely eradicated†*
	in year of discovery	*within 1 year*	*within 2 years*	*within 3 years*	*within 4 years*	*within 5 years*	
1950	0	2	0	1	0	0	3/6
1951	3	0	0	0	0	—	3/3
1952	8	2	1	2	—	—	13/14
1953	22	1	2	—	—	—	25/35
1954	7	3	—	—	—	—	10/15
1955	5	—	—	—	—	—	5/22
1956	—	—	—	—	—	—	0/28
1957	—	—	—	—	—	—	0/21

* Virus is considered to have been eradicated from treated centres of infection where infected trees were not found n 1956 and 1957.

† The fraction indicates the number of centres where outbreaks were successfully eradicated out of the total number treated.

The latent period of infection in trees is usually less than one year but may be up to two (POSNETTE, 1947; CROWDY and POSNETTE, 1947; LISTER and THRESH, 1955). Thus missed infections may still be found around outbreaks treated in 1956 and 1957 and outbreaks are not considered to have been eradicated unless infected trees were not found in each of these years. On this criterion virus has already been eradicated from the cacao around 59 of the 95 village centres of infection treated before 1956. At 39 centres no re-treatments were necessary and at five others they were only necessary the year the original outbreaks were discovered. Centres readily eradicated in this way were usually small and contained an average of 77 infected trees, compared with an average of 123 infected trees elsewhere.

Failure of the eradication measures was sometimes due to the appearance of a relatively small number of infected trees on or near the edge of the treated areas. These outlying infections usually appeared within three years of the initial treatments and had probably been infected by spread from the originally treated centres. They were readily controlled by one or more re-treatments involving only a small proportion of the perimeter trees.

In the cacao around 37 villages, virus has not been eradicated, or has only been eradicated after re-treatments carried out for more than three years, and new outbreaks are being started by mealybugs coming in from outside sources of infection. Thus new and remote outbreaks appear in the cacao around villages where no virus has been found for several years after earlier treatments. Furthermore, several of the village centres requiring numerous re-treatments are close to the abandoned areas and virus is clearly spreading into the cacao from outside, so that the cutting out measures are merely reducing the amount and extent of secondary spread.

Virus is considered to have been eradicated from farms in Ghana where no infected trees are found during 24 consecutive monthly inspections of the cacao in or within 30 yards of a treated farm. On this criterion virus has been eradicated from two per cent of the treated farms (HAMMOND, 1957) compared with 61 per cent of the village centres in Nigeria which have remained free from infection for at least two years. Clearly the Nigerian 30-yard treatments are very much more effective, although they involve large numbers of apparently healthy trees and an average of 10 were destroyed for every one found with symptoms (LISTER and THRESH, 1957a).

Recent experiments on control of swollen shoot disease by eradication methods

In 1954 a series of coppicing experiments was started to investigate whether the large scale destruction of apparently healthy trees in the 30-yard cutting-out treatments was justified, or whether comparable results could be achieved less drastically. Many outbreaks were selected and the obviously infected trees uprooted. All the apparently healthy trees within 30 yards of the obvious infections were then indexed by coppicing them and keeping the regeneration growth under regular symptom observation. Records were kept of the number of infected stumps found around each outbreak at each inspection. Around 48 of the outbreaks detailed observations were also made on the distribution of the infected trees in relation to those removed at the outset.

Detailed results of the coppicing experiments will be presented elsewhere, but a preliminary analysis shows great variation in the number of infected stumps found, even around outbreaks of similar size. More infected stumps were usually found around large outbreaks than around small ones and this is to be expected from the available information on spread (THRESH, 1958b). Of the infected stumps occurring within 30 yards of the cut-out trees, 51 per cent occurred within 5 yards, 35 per cent occurred between 5 and 10 yards, 8 per cent occurred between 10 and 15 yards and the remaining 6 per cent occurred between 15 and 30 yards; and the distribution was similar around outbreaks of all sizes. However, the intensity of latent infection is highest around the largest outbreaks, which explains why small ones are readily eradicated and justifies the use of cutting out measures based on the size of outbreak treated (*Table 1*).

When estimating the most efficient and economical cutting-out measures to be adopted for treating outbreaks, the additional latent and missed infections eradicated by a more drastic treatment must be balanced against the increased number of healthy trees involved. The coppicing experiments clearly show that the policy of treating the apparently healthy trees around all outbreaks to a uniform distance of 30 yards was unnecessarily severe, particularly around the smallest outbreaks. It is now recommended that apparently healthy trees should be removed to distances of 5, 10 and 15 yards around outbreaks of less than 6, 6 to 50 and 50 to 200 infected trees, respectively. The intensity of latent and missed infection in the apparently healthy trees remaining outside the cut-out areas will then be usually less than 5 per cent, which is not sufficiently high to justify the adoption of more drastic measures. However, the standing trees around each cut-out area must be inspected at regular intervals to ensure that the missed infections are detected soon after they produce obvious symptoms. Infected trees found during these re-inspections should be treated as new outbreaks and eradication measures applied according to the number of infections found.

The latest proposals will result in considerable economies, compared with the original cutting-out policy. Provisional changes were adopted in 1956 and until the end of 1957 the apparently healthy trees around outbreaks involving 1 to 10, 11 to 50 and >50 obviously infected trees were treated to 5, 15 and 30 yards respectively. The number of apparently healthy trees cut out in the treatment of 126 outbreaks totalling 10 379 infected trees was reduced from an estimated 90 947 (which would have been cut out if the 30-yard treatments had been applied) to 55 451; a saving of 35 596 on which the sum of £7 119 would have been paid out in compensation if the trees had been destroyed. If the latest recommendations had been adopted only 24 822 trees would have been cut out; a further saving of 30 529 trees and £6 106.

SUMMARY

An account and analysis is presented of the work of the Nigerian Department of Agriculture in attempts to control cacao swollen shoot disease. The decision to abandon eradication measures in two heavily infected areas is partly responsible for the deterioration in the position in recent years. Virus is spreading without check and causing a progressive decline in yield

in two abandoned areas, which are acting as dangerous foci of infection. The present situation in the abandoned areas is assessed and an outline given of possible development within them.

The present survey system is described and some of the difficulties experienced by the inspection parties discussed. Details are also given of proposals intended to increase the efficiency of the inspection service, which partly determines the build-up of infection outside the abandoned areas.

The routine measures used in attempts to eradicate virus from infected farms are described and their efficiency assessed. Until 1950 only trees found with symptoms were cut out, and only the smallest outbreaks were eradicated efficiently. Since 1950 the trees found with symptoms were cut out, together with the adjacent apparently healthy trees within 30 yards and virus was eradicated from the cacao around approximately two thirds of the treated villages. However, large numbers of apparently healthy trees were involved and coppicing experiments indicate that comparable success could have been achieved less drastically by treating outbreaks according to their size.

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An Acacia Weed of Uganda Grasslands

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In Uganda, large areas of grassland have been invaded by thorn-bush. Over 20 species of Acacia have been named in these grasslands, but probably the only one common to all districts is the species *Acacia hockii*, which is found in differing grassland communities from 2000 ft up to 6500 ft and occurs in densities varying from a few scattered trees to 1500 plants per acre. Although the growth rarely becomes impenetrable it does prevent livestock from grazing, and with the long-horned Ankole beast up to three quarters of the total herbage produced can thus be made inaccessible.

Late in 1952 a study of *Acacia hockii* was started with the object of trying to improve extensive ranch grazing lands. This work included a study of the plants as well as methods of control and eradication. Survey work covered most districts of the Uganda Protectorate but bush destruction studies were limited to Teso and Ankole districts. Details and tentative conclusions from five years of observation are given below.

DESCRIPTION OF ACACIA HOCKII

Plants of *Acacia hockii** occur in two distinct forms, either as a multi-stemmed bush resembling a gooseberry bush or as small trees 10 to 15 ft high, but occasionally up to 40 ft high. The young bark on the main stems is greenish-brown, but the old bark peels off in transparent brownish papery shavings. Thorns occur in pairs side by side but are variable in size and colour; they are usually straight, from an eighth to one inch long, and dull brown to white in colour. Occasionally thorns are absent on parts of the bush. The leaves are bipinnate with 10 to 20 pairs of leaflets to a pinna, and 4 to 12 pairs of pinnae per leaf. Leaf fall is very irregular and usually follows flowering or a long dry spell. In Ankole many bushes are bare in August. Flowers, golden yellow and globe shaped, are to be seen at almost all seasons of the year on individual bushes, but peaks of flowering occur in the dry spells of January and July. The pods are dehiscent on the tree, sickle shaped from two to four inches long and up to a quarter of an inch broad with slight constrictions around the seeds. The seeds may or may not fall immediately the pod opens as they often stay attached by a funicle up to a quarter of an inch long. A blow with an axe on the stem when the seeds are ripe will, however, cause them to fall. The seeds are brown, circular and laterally compressed. In size they are less than a quarter of an inch in diameter, about three sixteenths of an inch in thickness, and have a strong waxy cuticle.

* *A. hockii* has been classified as *Acacia stenocarpa*, *A. holstii*, and *A. seyal* var. *multijuga*. In the first edition of *Indigenous Trees of Uganda* (Eggeling, 1940), the name is given as *Acacia holstii* Taub. but in the second edition (Eggeling and Dale, 1951), the name *A. seyal* Del. var. *multijuga* Schweinf. ex Baker f. is given, and *A. stenocarpa* Oliv. is given as a synonym. Recently this species has been given the name *A. hockii De Wild.* (Director, Royal Botanic Gardens, Kew). The vernacular names have not suffered from these changes; the species being known as Kasaana in Luganda, Akaganda in Runyankore and Ekisim in Ateso.

GROWTH AND DEVELOPMENT OF A. HOCKII

During germination, the cotyledons are pushed above the ground and turn slightly green. The first leaf is pinnate with six to eight pairs of leaflets. The second leaf has one pair of pinnae each with six to ten pairs of leaflets. Subsequent young leaves have only one pair of pinnae, but the number of leaflets increases from 15 to 18 pairs by the tenth leaf. On the third to fifth leaf the stipules are clearly visible as small spines. The rate of growth varies with soil conditions and management, but even under relatively poor conditions a seedling can grow to two feet high in the first twelve months. The subsequent habit of growth is influenced by both fire and grazing.

With unrestricted growth, the plant produces one or two stems with a few side shoots. Browsing stimulates the production of more stems and branches, whilst fire (if severe) tends to check the side branches. These management differences enable the species to exist in the two widely different states. Under no burning and occasional grazing the 'gooseberry bush' develops (*Figure 1*) whilst under burning the tree form is found (*Figure 2*).

Figure 1. 'Gooseberry bush' type of growth which develops when growth of main stem is checked

Burning has a variable effect on the multiplication of the species. On the tree, the seeds are charred severely by a good grass fire, but on the ground some seeds escape without any visible damage. To simulate burning, seeds from unburnt bushes were heated on dry sand in a hot air oven and the germination potential compared with unburnt, unheated seed and with seed from burnt bushes. The results are summarized below.

Germination potential of A. hockii seeds

	Per cent
Unburnt seeds not treated	29
Unburnt seeds heated 10 mins. in 110°C. oven	64
Unburnt seeds heated 20 mins. in 110°C. oven	5
Unburnt seeds heated 30 mins. in 110°C. oven	1
Partially charred seeds from bushes after burning	9

Figure 2. Tree type of growth which develops under burning conditions. Note that trees do not interfere with the grazing

It will be noted that slight heating has a stimulating effect, but that prolonged heating or subjection to a fire kills many. The mortality of seeds on bushes is even higher than the above figure indicates, as completely charred seeds were not included in the tests.

Once the plant is established, it is hard to kill. After a fire, the burnt and singed leaves fall, and the plant appears to be dead, but within a fortnight, vigorous regrowth starts from the roots or from the thicker main stems. Similarly, if the plant is cut to ground level, new suckers soon appear. On one area of ' gooseberry bush ' plants, which was observed over a period, there were originally two stems per plant. Three months after cutting there were four stems per plant averaging 18 in. long. After a further three months the mean growth length was 45 in. with a maximum of 72 in. while 14 months after cutting, the general height of the regrowth was 5 to 6 ft and the area was indistinguishable from an adjacent uncut area.

BUSH CONTROL EXPERIMENTS

The first attempts to kill established stands combined cutting and burning. The idea was to cut the bush and to follow with burning three to four weeks later to kill the regrowth. The trials were not successful, first because labourers found it difficult to chop the bush to ground level when it was surrounded by grass, and secondly because of the difficulties of burning due to vagaries of the weather. The easiest way to chop the bush would be to burn the grass first but then there would not be enough grass to burn the regrowth. Alternatively, the cutting operation could be done by machine, but this line of study was not followed as the weather problem was considered to be too large a factor.

In January 1954, work with arboricides was started. It was decided because of costs to commence with solutions in water and to apply the chemical to the boles of uncut bushes. In subsequent application, dieseline

was used as diluent and applications were made to both cut and uncut stems. In all cases the butyl esters of 2,4-D and 2,4,5-T were used, and when the two were mixed they were used in the proportion of two parts 2,4-D to one part 2,4,5-T. A summary of the applications made during a period of just over two years is given below.

Chemical	*Diluent*	*Concentrations of chemicals*	*Methods of application*
2,4-D	Water	5 and 10%	Knapsack spray to uncut boles
2,4-D and 2,4,5-T	Water	12 and 5%	Knapsack spray to uncut boles
2,4-D and 2,4,5-T	Dieseline	1 and 2%	Knapsack spray to uncut boles
2,4-D and 2,4,5-T	Dieseline	1, 2 and 3%	Paint brushes to cut stems
2,4-D and 2,4,5-T	Dieseline	2 and 4%	Knapsack spray to cut stems

Considering the practical application of these trials it is apparent that accessibility and ease of application are two of the major considerations. With plants in the tree form, it was easy to apply the spray to uncut stems with a knapsack sprayer but with the available equipment only 50 trees could be treated with each gallon. To obtain complete coverage of a foot-wide band all round the trunks resulted in much of the spray missing the tree. The efficiency of this type of application might, however, be improved by modifications in spray nozzles. It was almost impossible to get a complete circular cover of spray on ' gooseberry bush ' stems and only 50 stems could be treated with one gallon.

The lowest rate of chemical application was with paint brushes to cut stems. Only one pint was used to every thousand stems. The percentage kill, however, was not very high. With the 3 per cent concentration only 25 per cent of the stems were dead at the end of six months; the remainder were growing by the production of suckers from the lower parts of the plant.

The application of chemical with knapsack to cut stems ensured that the area around the stems was soaked with spray. One trial with a 2 per cent spray had an 88 per cent kill at the end of 6 months and a similar result after 12 months, but another trial with the same spray, strength and similar cutting, gave lower results. In the former trial the area was burnt after spraying, whilst in the second, the area was burnt three weeks before cutting and spraying.

The persistence of the species and the difficulties of assessing results are illustrated clearly by the trial with bole spray on plants of tree form. The trunks varied from 1½ to 4 in. in diameter. Three months after application 86 per cent of the trees had no green leaves. At the end of 10 months, however, only 15 per cent were declared dead; while 65 per cent were growing from suckers below the point of application, and 20 per cent were growing from the old stems.

The costs of using the 4 per cent mixed chemical in dieseline applied to cut stems were calculated in detail. The workers operated in threes, two men cut the bush and one man followed very closely with a knapsack to spray the stumps.

The cost of clearing 15 acres using the above system was just under *Shs* 40/- per acre. The distribution of the cost was:

Cost of supervision	3·0 per cent
Cost of cutting labour	8·5 per cent
Cost of spraying labour	4·5 per cent
Cost of dieseline	61·0 per cent
Cost of 2,4-D and 2,4,5-T	23 per cent

The costs are based on mean labour wages of *Shs* 50/- per month, and minimum prices for dieseline, 2,4-D and 2,4,5-T. Under field conditions, however, the costs are likely to be higher as the chemicals cost more, and the rate of working may be less with less detailed supervision. From the analysis it will be noted that under the trial conditions, labour cost is very low in relation to the cost of dieseline or the cost of the chemicals. The rate of working in this trial was approximately 0·6 acre per man employed in cutting per day.

In a previous trial, in order to reduce the cost of chemicals, a trial was conducted with ammonium sulphamate. This chemical is more expensive per unit weight than the chlorophenoxyacetic acid compounds, but it can be used in water instead of using dieseline. In the trial, a usual two per cent concentration of 2,4,5-T and 2,4-D in dieseline and a solution of ammonium sulphamate in water costing the same as the dieseline solution were compared. The dieseline solution severely checked the regrowth from cut stems, but the ammonium sulphamate appeared to have no effect.

In one trial, dieseline alone was applied to uncut stems. This appeared to have little effect after the first scorch.

No trials were undertaken with arsenical compounds, because of the toxicity of these chemicals to man and domestic animals. In addition, it would have been difficult to apply them to small diameter stems using the method suggested by West (1947). This involves the longitudinal splitting of the stump before applying the chemical. With large diameter trunks this would work effectively but with stumps less than an inch in diameter, the labour cost would be more than doubled.

DISCUSSION

Only two uses have been found for *A. hockii*. It is reported that before the days of matches the trees were used as a tinder box. A piece of wood from any tree was rotated vigorously in a small hole in the Acacia trunk, and the resultant heat used to ignite bark cloth. The other use is in the construction of cattle kraals in Ankole district. The first use is of no great importance these days, while the second use is probably only one of convenience, *Acacia hockii* being the most common thorn tree available.

It does, however, possess certain agronomic advantages. It is a deep rooted leguminous tree, on the young leaves of which cattle and goats occasionally browse, but its main benefit to livestock is indirect, as a result of the soil improvement with each leaf fall. In central Ankole, samples show that soil near the trunks of the *Acacia* spp. is richer in potassium than the surrounding soil. This results in the ground being covered with the highly palatable and nutritious grass, *Brachiaria brizantha*.

The chief disadvantage of *A. hockii* is the reduction in potential grazing

area. This reduction is most serious when the species is in the 'gooseberry bush' stage of growth and least serious when it has developed into a tree over six feet in height. In the driest parts, for example in the Karamoja district, the species competes with grasses for the available water, but in districts with a fairly well distributed rainfall of above 30 inches per annum, this competition should not be serious.

To reduce the effect of *A. hockii* on the utilization of the grazing, efforts should be made to convert the 'gooseberry bush' into a tree. Cutting encourages the formation of the 'gooseberry bush' whilst fire has the opposite effect. The effect of a good fire is most noticeable on the lower portions of the bush, as all the side branches under a quarter of an inch in diameter will be burnt to ash. This means that suckers and side shoots will be destroyed and only the main stem will survive. Subsequent recovery of the small branches must be checked again until the head of the tree is out of reach of the fire.

The alternative to controlled grazing and burning is to eradicate the species completely. The cost of such improvement works must, however, be related to the increase of grazing value. In Ankole the value of unenclosed extensive grazing, converted into beef, is probably *Shs* 20/- per acre per year, while under intensive grazing conditions it is probably twice this sum. Assuming that a burn has no effect on the growth of grass other than to remove dead herbage, the cost of burning May–June grass in July is to lose a third of the year's grass growth, valued at *Shs* 6/67 per acre. This appears to be the minimum age of grass to burn for any clearance operation.

If the bush denies half the grass to the grazing animal, its removal would double the value of the grazing. Removal by cutting and the application of arboricide would in these circumstances take at least four years to pay off, while manual cutting alone would cost the equivalent of a half to one year's grazing.

The alternative to chemicals or cutting at ground level is to dig around the base of the tree and cut the stem below ground level. This was tried, but the ground was hard and the job was unpopular with the labour and difficult to supervise. A good kill was obtained but on a large scale the cost would be too high and success would depend on good supervision.

Similar arguments could be used to assess the efficiency of mechanical cutting. With a tractor used continuously throughout the year, the minimum cost of spares, oil, paraffin and depreciation is probably *Shs* 11/- per hour. Add to this the cost of driver, plus the cost of running a bush-cutting machine, and the total cost per hour is high. But it may be argued that a tractor works more quickly than manual labour. With a cutting machine three feet wide a tractor must travel two miles to cover an acre, and the maximum rate of working is probably three miles per hour. Thus, the cost of cutting mechanically is probably *Shs* 12/- per acre compared with the cost of manual cutting at less than *Shs* 4/- per acre. There are, however, advantages to be gained by using a mechanical cutter which are difficult to estimate in terms of cash return. For example, if labour is in short supply, machines may do a job it would be impossible to do manually. Similarly, if tractor drivers work shifts, one tractor plus cutter will, in a twelve hour day, cut as much as one labourer would cut in 30 working days.

In dealing with trunks, in contrast to bush, a slightly different approach is required. With this type of growth the quantity of grass denied to cattle is less. Consequently, the improvement in carrying capacity after the bush is removed will be less. Here, selective clearing to reduce the density together with burning to check suckers and side growth will be all that is needed.

Finally the influence of livestock on the vegetation must not be forgotten. Goats in particular are very fond of young Acacia shoots. Cattle have also been observed on a number of occasions to be eating the leaves from young rapidly growing suckers of *Acacia hockii*. The two combined could save a considerable number of man hours but the bush must first be stimulated to produce suckers either by cutting or burning. The management must also be strict, and the goats concentrated for three or four years to have any effect (Oates, 1956).

CONCLUSIONS

As a result of this study it is apparent that the problem of thorn bush control and eradication does not have a straightforward answer. Thorn bushes may not be desirable, but the cost of their control or removal must be considered in relation to the cost of labour and the value of grazing. For so long as fire is used on grazing areas this must be regarded as the major bush-controlling factor. When a management involving no fire is adopted, the cost of chemicals and machines must be compared with the cost of manual labour.

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The Effects of Arboricides on East African Trees and Shrubs—II

Species of the Brachystegia–Pseudoberlinia *Woodland*

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The *miombo* woodland dominated by species of *Brachystegia* and *Pseudoberlinia* is the most widespread vegetation type of the western and southern parts of Tanganyika and covers nearly one half of the total area of the country. It also extends over considerable portions of Northern Rhodesia, Nyasaland, Portuguese East Africa and Angola. Its distribution depends more on climate than on soil type and one of its main requirements appears to be an annual rainfall between about 30 and 45 in. with a single peak distribution and a relatively long dry season (Gillman, 1949). This type of open, deciduous woodland is the principal habitat in Tanganyika of the tsetse fly *Glossina morsitans*, a carrier both of bovine trypanosomiasis and of human sleeping sickness and, largely because of the presence of tsetse, most of the *miombo* region is undeveloped agriculturally and supports a very small population.

One of the main objects of the arboricide work started by the Colonial Pesticides Research Unit in 1953 was to determine to what extent chemical arboricides were likely to be of value in the reclamation of tsetse-infested country. At this time the main tsetse-clearing scheme in *miombo* country in Tanganyika was being undertaken by the Overseas Food Corporation (now the Tanganyika Agricultural Corporation) in their farming area at Urambo in the Tabora district. The clearing operations, which involved both discriminative bush-clearing and sheer felling on a large scale, were planned and supervised by the East African Tsetse and Trypanosomiasis Research and Reclamation Organization (E.A.T.T.R.R.O., 1955) who suggested that an assessment of the potentialities of arboricides should be made in this district. A trial with the chemicals 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) and 2,4-dichlorophenoxyacetic acid (2,4-D) was accordingly started at Urambo in May 1954.

THE EXPERIMENTAL SITE

The site chosen for the trial was located in a homogeneous area of well grown *miombo* dominated by *Brachystegia spiciformis* together with numerous *Pseudoberlinia globiflora* and *Burkea africana*. The trees were up to 40 to 45 ft high and up to 30 in. in diameter at the base of the trunk. Such large specimens, however, were relatively infrequent and there were much larger numbers of smaller trees with trunks 3 to 12 in. in diameter reaching heights of 15 to 30 ft. In all there were approximately 100 trees per acre. A list of the main species present is given in *Table 1* together with estimates of their relative frequency and the average basal diameter of the trunks.

Table 1. Main tree species occurring in experimental area with estimates of numbers and trunk diameter

Species	*Number per acre*	*Mean basal diameter of trunk (in.)*
Brachystegia spiciformis *Benth.* (*Large tree*)	17·2	10·6
Pseudoberlinia globiflora (*Benth.*) *Duv.* (*Medium or large tree*)	10·6	7·3
Burkea africana *Hook.* (*Large tree*)	9·5	8·2
Diplorhynchus mossambicensis *Benth.* (*Small or medium tree*)	8·6	6·5
Pseudolachnostylis maprouneifolia *Pax.* (*Medium tree*)	7·8	6·0
Pterocarpus angolensis *D.C.* (*Medium or large tree*)	6·0	6·8
Combretum guenzii *Sond.* (*Small tree*)	4·9	5·6
Combretum binderanum *Kotschy.* (*Small tree*)	3·2	5·9
Lannea schimperi (*Hochst. ex A. Rich*) *Engl.* (*Small tree*)	2·6	5·9
Terminalia sericea *Burch.* (*Small tree*)	2·6	3·1
Swartzia madagascariensis *Desv.* (*Medium or large tree*)	2·6	7·2
Combretum apiculatum *Sond.* (*Small tree*)	2·3	3·8
Hexalobus monopetalus (*A. Rich*) *Engl. & Diels.* (*Small tree*)	2·0	3·6
Xylopia antunesii *Engl. & Diels.* (*Small tree*)	2·0	6·0
Dichrostachys glomerata (*Forsk.*) *Chiov.* (*Shrub or small tree*)	1·7	3·6
Ximenia americana *L.* (*Shrub*)	1·4	2·9
Commiphora pilosa *Engl.* (*Small tree*)	1·4	5·4
Commiphora *spp.* (*Small trees*)	1·4	5·4
Pterocarpus chrysothrix *Taub.* (*Small or medium tree*)	1·1	4·3
Strychnos pungens *Solered.* (*Shrub*)	1·1	2·4
Strychnos *spp.* (*Shrubs or small trees*)	1·1	3·6
Crossopteryx febrifuga (*Afzel. ex G. Don*) *Benth.* (*Small or medium tree*)	1·1	5·2
Dalbergia stuhlmannii *Taub.* (*Small tree*)	1·1	5·4
Albizzia harveyi *Fourn.* (*Medium tree*)	1·1	6·8
Monotes adenophyllus *Gilg.* (*Medium tree*)	1·1	7·2
Diospyros mespiliformis *Hochst. ex A.DC.* (*Shrub or small tree*)	0·9	5·3
Schrebera koiloneura *Gilg.* (*Shrub or small tree*)	0·6	4·0
Lonchocarpus capassa *Rolfe.* (*Medium tree*)	0·6	4·5

The ground layer was dominated by tall grasses such as *Hyparrhenia* (*H. rufa* and other species), *Panicum maximum*, and species of *Andropogon* which reached a height of 6 to 8 ft in the rainy season lasting from November to April. At some time during the dry season from May to October, usually in July, the area was swept annually by fierce grass fires so that the vegetation included very few of the smaller shrubs. The fires also appeared to be suppressing the regeneration of *Pseudoberlinia* and other species. Numerous small shoots of these trees were present, arising either from seed or as root suckers, but they seldom reached heights above 2 to 3 ft before being burnt back to ground level again. The experimental site was not protected from the annual burn.

EXPERIMENTAL METHODS

When the experiment was laid out the identity of the majority of the trees was not known to the author. In order to ensure that the treatments covered a representative selection of species, therefore, they were applied to groups of trees selected at random. The area was marked out into a number of half-acre plots and each treatment was applied to 30 trees chosen at random within a plot. On a few plots this number represented the total number of trees present but on most it accounted for about half the total. In view of the large number of species subsequently identified, 40 species in all, it became evident that a sample of 30 trees was too small to permit detailed comparisons between treatments except for a few of the most numerous and constant species. It was found, however, that the differences between the final effects of the treatments were relatively small so that the results are sufficient to give an indication of the relative susceptibility of quite a large number of species.

The treatments tested were sprays of 2,4,5-T and 2,4-D applied to the basal 12 to 18 in. of the trunks with an Oxford Precision sprayer. The bark was frilled by a ring of downwardly directed cuts near the ground and the sprays were applied so that the liquid entered the cuts and ran down to ground level. A 'low-volatile' (butoxyethanol) ester formulation of 2,4,5-T (Weedone 2,4,5-T) was used at concentrations of 1·0, 2·0 and 4·0 per cent (w/v) of acid both in diesel oil and as an emulsion in water. A similar low-volatile ester of 2,4-D (Weedone L.V. 4) was used at 4·0 per cent in oil and a 2:1 mixture of butoxyethanol esters of 2,4-D and 2,4,5-T (Weedone Brushkiller 64) was also tested at total chemical concentrations of 1·0, 2·0 and 4·0 per cent in diesel oil. The chemical treatments were compared with frilling or ring-barking without spraying, the ring of bark removed being 1 to 2 ft wide.

A volume of 4 000 ml of spray solution was used for each group of 30 trees, the average basal diameters of which varied from 6·5 to 9·1 in., so that the volume of spray expressed in millilitres per inch diameter of trunk varied from 15 to 10. If all trees in the experimental area had been treated, approximately three gallons of spray per acre would have been used. With a 1·0 per cent solution this is equivalent to 0·3 lb of chemical per acre.

When the sprays were applied in May 1954 the trees were in full leaf and the grass growth was at its maximum at the end of the rainy season. Approximately two months later the area was burnt and most of the trees lost their leaves. Few effects of the treatments could thus be observed until fresh leaf growth took place in December, seven months after spraying. Observations on the treated trees were continued at intervals until March 1957 when the final assessment was made.

Supplementary trials were carried out on *Pseudoberlinia globiflora* in May 1954 at Mpwapwa in the Central Province and on *P. globiflora* and *Brachystegia spiciformis* at Urambo in July 1955.

EXPERIMENTAL RESULTS

(a) *The main experiment on* miombo *species*

When the first assessment of the effects was made, seven months after spraying, a flush of new growth was taking place but about half of the trees

were still leafless in unsprayed areas. The ring-barked trees and those frilled without spraying appeared very similar to untreated trees as also did those treated with 2,4,5-T emulsions. On the plots treated with oil solutions, however, larger proportions of the trees were still leafless and some of the foliage produced was distorted. A number of *Pseudoberlinia* and *Brachystegia* were exuding a gummy substance through small cracks in the bark, the bark of most of the *Pterocarpus* spp. was dead and decaying while several *Commiphora* spp. and *Lannea schimperi* had already fallen. With the oil treatments a total of 50 per cent of the trees was recorded as dead or dying.

After a further seven months new bark had grown across the frill with most of the trees which were frilled without being sprayed, especially with *Brachystegia* and *Pseudoberlinia*. Frilling alone was sufficient to kill a few trees, such as *Commiphora* spp. while with about half of the *Burkea* and *Pterocarpus* the cut had not healed. Ring-barking was effective on a larger number of species. With *Brachystegia*, *Pseudoberlinia* and *Pterocarpus* the bark above the ring had dried up and with most of the *Burkea* and *Pseudolachnostylis*, although the bark still appeared normal, it showed no tendency to close the gap. A number of trees, however, including *Diplorhynchus*, *Combretum guenzii*, *Hexalobus* and *Xylopia* recovered from ring-barking.

On the plots receiving the spray treatments the effects of 2,4,5-T emulsions were becoming apparent 14 months after spraying. The bark of many *Brachystegia* and *Pseudoberlinia* had dried up, though on some it was still normal, while *Commiphora* and *Lannea* were dead and fallen. With *Burkea* and *Pseudolachnostylis* the bark still appeared healthy although no new growth had developed across the frill and most of these trees subsequently died.

The greatest effects were evident on the plots treated with oil solutions of 2,4,5-T and 2,4-D where a total of 73 per cent of the trees was now dead or dying. The bark of most of the *Brachystegia*, *Pseudoberlinia* and *Burkea* had either dried up or was riddled with the holes of wood-boring insect larvae. *Pseudolachnostylis* was dead and the bark was splitting from the trunks up to a height of 15 ft. Some *Pterocarpus* had fallen, though a few had succeeded in producing a new layer of bark below the decaying tissues affected by the chemical, and relatively few species remained unaffected. Among the least affected were *Diplorhynchus*, *Combretum apiculatum* and *Strychnos* spp., many of which had grown fresh bark across the treated zone.

Another assessment was made in November 1955, 18 months after spraying, and there was little change in the condition of the trees except for a small increase in the numbers with dead bark. The increase was particularly evident with those *Pseudoberlinia* and *Brachystegia* attacked by wood-boring larvae whose bark was recorded as living at the earlier observation.

It was also evident that the larger trees were taking a much longer time to show the effects of treatment than were the smaller ones. The effect of size on the speed of response is illustrated in *Table 2* which shows the numbers of trees in various size classes which were recorded as dead at different intervals after spraying. It will be observed, for example, that, whereas the majority of trees with trunks less than 2 in. in diameter were dead seven months after treatment, it took 14 months for a similar proportion of those in the

Table 2. Percentages of trees in different size classes with dead trunks at varying intervals after spraying (oil treatments only)

Basal diameter of trunk in.	Number of trees (all species)	Per cent with dead trunk			
		Months after spraying			
		7	14	18	34
Below 2	19	89	100	100	100
2–5	81	54	87	87	88
5–10	80	48	59	68	75
10–15	22	30	68	78	74
15–20	7	0	29	71	83
Above 20	1	0	0	0	(100)
Mean of all sizes		50	73	79	82

2 to 5 in. class to die, while those more than 15 in. in diameter remained apparently healthy for still longer periods.

The final assessment of this trial was made in March 1957, 34 months after the sprays were applied, and the results are summarized in *Tables 3* and *4*. *Table 3* shows the percentage of all species killed by the various treatments, the second column referring to those with dead trunks and the third to those with dead trunks and no regeneration.

A certain amount of regeneration was noted 14 months after spraying (8 per cent of the total dead trees) and more had appeared after 18 months (11 per cent). Both these observations were made after the dry season burn, however, so that the degree of regeneration was probably underestimated. At the final observation during the rains particular care was taken to record regrowth and all new growth up to a distance of 3 ft from the base of the trunks was noted. Beyond this distance, with the root-suckering species such

Table 3. Total percentage kills of all species 34 months after application of various arboricide treatments

Treatment	Concentration per cent	Per cent with dead trunk	Per cent dead without regrowth
Ring-barked	—	63	27
Frilled	—	32	21
Frilled, 2,4,5-T in oil	1·0	77	47
	2·0	93	70
	4·0	92	60
Frilled, 2,4-D–2,4,5-T mixture in oil	1·0	57	40
	2·0	83	77
	4·0	92	70
Frilled, 2,4-D in oil	4·0	83	77
Frilled, 2,4,5-T emulsion	1·0	77	57
	2·0	53	50
	4·0	74	73
Mean of chemical treatments		78·1	62·1

as *Pseudoberlinia*, it was not possible to determine whether the shoots were produced as a result of the treatment or whether they were present at the time of spraying. On this basis a total of 20 per cent of the dead trees eventually produced regrowth. With the majority of the trees that had regenerated during the previous rains, the shoots were killed back by the dry season burn and most of the regrowth noted at the final assessment was the result of a single season's growth. With most species it appeared likely that subsequent burns would similarly limit the further development of regrowth.

Table 3 shows that frilling alone killed the trunks of approximately one third of the trees, mostly *Commiphora* spp. and the smaller specimens of *Burkea*, *Brachystegia* and *Pterocarpus*. Ring-barking, as would be expected, killed a larger number but more than half produced regrowth. The chemical treatments in general gave higher percentage kills than ring-barking and resulted in a smaller degree of regeneration so that, basing kill on the numbers of dead trees without regrowth, application of the chemicals killed rather more than twice as many as ring-barking.

The differences between the chemical treatments, however, were relatively small. There is evidence that the 2·0 and 4·0 per cent oil solutions of 2,4,5-T and the 2,4-D–2,4,5-T mixture were somewhat more effective than the 1·0 per cent solutions, and 2,4,5-T alone appears to have given a slightly

Table 4. Relative susceptibility of various miombo *trees to 2,4,5-T and 2,4-D. With the more numerous species the effects of diesel oil solutions and emulsions in water are compared. With the rest the data refer to a mean of all chemical treatments. Effects assessed after 34 months*

	Diesel oil solutions			*Emulsions in water*		
Species	*Number treated*	*Per cent with dead trunk*	*Per cent dead without regrowth*	*Number treated*	*Per cent with dead trunk*	*Per cent dead without regrowth*
Brachystegia spiciformis	38	97	79	10	80	80
Pseudoberlinia globiflora	15	93	40	18	100	100
Burkea africana	18	94	72	6	50	50
Diplorhynchus mossambicensis	24	46	29	8	12	12
Pseudolachnostylis maprouneifolia	14	100	93	8	62	50
Pterocarpus *spp.*	16	88	75	5	60	40
Combretum guenzii	10	80	50	5	40	20
All treatments						
Combretum binderanum	9	78	67			
Combretum apiculatum	9	55	33			
Commiphora *spp.*	8	100	88			
Swartzia madagascariensis	8	88	75			
Terminalia Sericea	7	100	57			
Strychnos *spp.*	6	50	33			
Dalbergia *spp.*	6	83	17			
Lannea schimperi	6	100	100			
Hexalobus monopetalus	5	100	80			
Dichrostachys glomerata	5	100	100			
Crossopteryx febrifuga	4	25	0			
Albizzia harveyi	4	25	25			
Monotes adenophylla	4	100	100			

more effective kill of trunks than 2,4-D or the mixture. The 2,4,5-T emulsions have killed a slightly smaller number of trunks than the oil solutions but there was less regeneration with these treatments and, if kill without regrowth is considered, the emulsions appear to have been as effective as the oil solutions. Reference to *Table 4*, however, shows that, although emulsions of the chemicals in water were equally or more effective than oil solutions on *Brachystegia* and *Pseudoberlinia*, the most numerous species, they were considerably less effective on most other species. Thus although the emulsions killed as large a number of trees as the oil solutions, they were effective on a much smaller number of species.

The list of the percentage kills of different species given in *Table 4* shows that oil solutions of the chemicals killed a high percentage of the trunks of most species. Among the more resistant were *Diplorhynchus*, *Combretum apiculatum*, *Strychnos* spp., *Crossopteryx* and *Albizzia harveyi*. Varying degrees of regeneration occurred after 34 months but, with the majority of species, was restricted to 25 per cent or less of the trees whose trunks were killed. The species regenerating in greater numbers, arranged in order of decreasing degree of regeneration, were *Dalbergia*, *Pseudoberlinia*, *Terminalia*, *C. apiculatum*, *C. guenzii*, *Diplorhynchus* and *Strychnos* spp.

The final kill of the aerial parts of the trees as an average of all the chemical treatments was 78 per cent and 62 per cent of the total was killed without producing regrowth. The comparable data for ring-barking were 63 and 27 per cent. A quarter of the dead trunks had fallen, mostly the smaller trees but including some *Brachystegia* with trunks up to 15 in. in basal diameter. With most of the remainder the upper branches had broken off leaving only the main trunk standing.

(b) *Supplementary experiments on individual species*

Additional information on *miombo* species was obtained in two further trials. One, on *Pseudoberlinia globiflora*, was carried out at Mpwapwa in May 1954 when the trees were in leaf during the rains. The other, on *Pseudoberlinia* and *Brachystegia spiciformis*, was situated at Urambo, in the same area as the main trial, and was sprayed in July, shortly after the trees had lost their leaves in the early part of the dry season, after an early burn. In the first trial a low-volatile (butoxyethanol) ester of 2,4,5-T was compared with and without frilling at 2·0 and 5·0 per cent in diesel oil and at 1·0 and 2·5 per cent in water using twice the volume per tree. The emulsion treatments included 10 per cent of diesel oil. In the second trial more volatile esters of 2,4,5-T (*n*-butyl) and 2,4-D (*iso*propyl) at a concentration of 1·0 per cent in diesel oil were compared on the two species with and without preliminary frilling. In both trials each treatment was applied to a group of 10 trees. The final results of the two experiments are summarized in *Table 5*.

These results help to confirm the evidence from the main trial that the above-ground parts of *Brachystegia* and *Pseudoberlinia* are susceptible to oil-based sprays of 2,4,5-T and 2,4,-D applied to the base of the trunks after frilling. They also show that application without frilling gave a considerably reduced kill and that the ' low-volatile ' ester employed at Mpwapwa did not differ greatly in effectiveness from the more volatile material used

Table 5. Effects of 2,4,5-T and 2,4-D esters on Pseudoberlinia globiflora *and* Brachystegia spiciformis *assessed 20 months (Urambo) and 29 months (Mpwapwa) after application*

Species		Pseudo berlinia				Brachystegia	
		Mpwapwa		*Urambo*		*Mpwapwa*	
Treatment	*Conc.* %	*Number with dead trunk*	*Dead without regrowth*	*Number with dead trunk*	*Dead without regrowth*	*Number with dead trunk*	*Dead without regrowth*
Frilled only		3	3	3	2	5	5
Frilled, diesel oil		7	6	—	—	—	—
Frilled, 2,4,5-T in oil	1·0	—	—	10	10	9	9
	2·0	10	5	—	—	—	—
	5·0	10	8	—	—	—	—
No frill, 2,4,5-T in oil	1·0	—	—	0	0	0	0
	2·0	3	3	—	—	—	—
	5·0	4	3	—	—	—	—
Frilled, 2,4,5-T emulsion	1·0	5	5	—	—	—	—
	2·5	3	2	—	—	—	—
No frill, 2,4,5-T emulsion	1·0	0	0	—	—	—	—
	2·5	0	0	—	—	—	—
Frilled, 2,4-D in oil	1·0	—	—	9	9	10	9
No frill, 2,4-D in oil	1·0	—	—	1	1	1	1
Number per treatment		10		10		10	
Volume of spray per tree		200 *ml*		200 *ml* (400 *ml with emulsions*)		200 *ml*	
Mean basal diameter		6·5 *in.*		8·1 *in.*		8·2 *in.*	
Estimated trees per acre		100		100		100	
Volume of oil per acre		2·2 *gal*		2·2 *gal*		2·2 *gal*	
Chemical per acre at 1·0%		0·22 *lb*		0·22 *lb* (0·44 *lb with emulsions*)		0·22 *lb*	

at Urambo. The importance of frilling is further emphasized by the fact that diesel oil alone applied to frilled trunks killed a higher proportion than 2,4,5-T applied to the uninjured bark at concentrations up to 5·0 per cent. When the trunks are frilled the concentration of chemical appears to be relatively unimportant over the range tested and 1·0 per cent of 2,4,5-T in oil was no less effective on *Pseudoberlinia* than 5·0 per cent. Diesel oil alone gave a less complete kill of the above-ground parts but in the one trial where it was used only one of the affected trees produced regrowth.

Emulsions, however, were considerably less effective than in the main trial where, as shown in *Table 4*, all *Pseudoberlinia* were killed by these treatments. Similar treatments in the Mpwapwa trial only gave kills of 30 to 60 per cent while, without frilling, emulsions produced no visible effect. There were also anomalies in the degree of regeneration following treatment. At Mpwapwa, as in the main trial, regrowth in the form of root suckers occurred round the base of a moderate number of trees whose above-ground parts had been killed by 2,4,5-T in oil. In the trial on *Brachystegia* and *Pseudoberlinia* at Urambo, however, no regeneration was recorded from the 19 *Pseudoberlinia* killed by 2,4,5-T and 2,4-D and was only present on one of the same number of dead *Brachystegia*. In this trial it was noted with

both species that, only four months after treatment, gum was exuding from holes in the trunk made by wood-boring insects so that it was possible to observe that the trees were dying even though they were still leafless.

Table 6 summarizes the relative susceptibility of the more important species.

Table 6. Relative susceptibility of miombo *species to 1·0 to 2·0 per cent solutions of 2,4,5-T in diesel oil applied as basal sprays to frilled trunks*

More than 90 per cent of above-ground parts killed	*Number regenerating*	*Effect of ring-barking S=susceptible R=resistant*
Brachystegia spiciformis	*Few*	*S*
Pseudoberlinia globiflora	*Many*	*S*
Burkea africana	*Moderate*	*Some S*
Pseudolachnostylis maprouneifolia	*Few*	*Most R*
Commiphora *spp.*	*Few*	*S*
Terminalia sericea	*Moderate*	*R*
Lannea schimperi	*None*	*S*
Hexalobus monopetalus	*Few*	*R*
Dichrostachys glomerata	*Few*	*R*
Monotes adenophylla	*None*	*?*
75 to 90 per cent of above-ground parts killed		
Pterocarpus *spp.*	*Few*	*Some S*
Combretum guenzii	*Moderate*	*R*
Combretum binderanum	*Few*	*R*
Swartzia madagascariensis	*Few*	*Most R*
Dalbergia *spp.*	*Many*	*R*
Less than 75 per cent of above-ground parts killed		
Diplorhynchus mossambicensis	*Many*	*R*
Combretum apiculatum	*Moderate*	*R*
Strychnos *spp.*	*Many*	*R*
Crossopteryx febrifuga	*All*	*R*
Albizzia harveyi	*Few*	*?*

DISCUSSION

The results of this series of experiments suggest that the most effective method of using 2,4,5-T and 2,4-D as basal sprays on *miombo* species is by the application of oil solutions to frilled trunks. This type of application has also been found to give the best results on some of the larger East African *Acacia* species (IVENS, 1958). As was found with the *Acacias*, increasing the concentration of chemical above 1·0 to 2·0 per cent (w/v) of acid does not greatly increase the effectiveness of the spray and 1·0 per cent has given over 90 per cent kill of the above-ground parts of the three main species, *Brachystegia*, *Pseudoberlinia* and *Burkea*, as well as many of the less numerous species.

By contrast with the *Acacias*, however, there is no evidence that 2,4,5-T is markedly superior to 2,4-D in its effects on the main *miombo* species. These species are susceptible to ring-barking and, although the majority are able

to recover from frilling alone, the application of a relatively low concentration of arboricide in oil prevents callus formation across the frill. With *Pseudoberlinia*, diesel oil alone frequently appears to be sufficient to prevent callus formation and, in one trial, emulsions of 2,4,5-T in water had the same effect resulting in high degrees of kill without regrowth. In the other trial where emulsions of 2,4,5-T were used on *Pseudoberlinia*, however, they were considerably less effective and gave results more in line with those obtained on *Acacias* and various other tree species. In general the oil solutions had a more rapid effect than the emulsions as was evidenced by the exudation of gum from the trunk. This suggests that the chemical was being translocated upwards from the point of application while the slower action of the emulsions and of diesel oil alone suggests that they were acting mainly by preventing the healing of the frill.

Although the aerial parts of the main species are readily killed by application of 2,4,5-T or 2,4-D, the root systems appear to be less affected and there is a tendency for regrowth to occur either from the trunk just below ground level or from root suckers. Regeneration was particularly frequent with *Pseudoberlinia*, in the main trial appearing with more than half of those killed by the oil solutions and at Mpwapwa occurring with about a third. In the supplementary trial on this species at Urambo, however, regeneration was negligible and it is possible that the difference is connected with the time of year at which the sprays were applied. In both cases where the treatments had been applied during the rains there was considerable regeneration, while where the application was made in the early dry season shortly after a burn there was very little.

In the trials on *Acacia* species referred to above the seasonal effect was different and *A. hebecladoides* regenerated less when sprayed during the rains than during the dry season when leaf fall was taking place. In this case the position was not complicated by the effect of a fire and it is possible that the fire was the operative factor on *Pseudoberlinia* at Urambo rather than the seasonal condition of the trees. It is evident, however, that much more information is required on the relative effectiveness of arboricides at different times of year and on the interaction of burning and chemical treatment before any general conclusions about these factors can be drawn.

In experiments on *Brachystegia* and *Pseudoberlinia* in other parts of Africa arboricides have been considerably less effective than in the present trials. In Southern Rhodesia, for instance, CLEGHORN *et al.* (1958) found 1·0 per cent oil solutions of 2,4,5-T and 2,4-D ineffective as basal sprays applied to partial frills or to uncut bark. Application to freshly cut stumps was more effective but kills rarely exceeded 20 per cent with *Pseudoberlinia* or 50 per cent with *Brachystegia*. There was evidence that the greatest kills were obtained during the dry season but even at the most favourable period these chemicals did not give satisfactory results. Arsenic appeared more promising. Similar results have been reported from trials on secondary *Pseudoberlinia–Brachystegia* woodland in Nyasaland (JACKSON, 1955) where, although 2,4,5-T and 2,4-D gave good kills of the aerial parts of the trees, they were regarded as unsatisfactory because they did not prevent the growth of root-suckers. On standing trees arsenic was found to be more effective than the growth-regulating chemicals. The climate of Southern Rhodesia is very

different from that of Tanganyika and, in general, the *Pseudoberlinia–Brachystegia* woodland consists of smaller trees. It is probable that the longer dry season and the low temperatures of the Rhodesian winter contribute to the greater resistance of trees growing under these conditions and the effects of previous cutting may also be of importance. The absence of fires in the Rhodesian and Nyasaland trials, however, is likely to be the main reason for the greater development of regrowth noted in these territories and may also be partly responsible for differences in the effects on the aerial parts of the trees.

Under the conditions of the present trials the application of 2,4,5-T at rates of the order of 0·5 to 1·0 lb/acre in about three gallons per acre of diesel oil killed the above-ground parts of approximately 90 per cent of the trees in *miombo* woodland and 60 to 70 per cent were killed without regenerating. The practical implications of these findings must now be briefly discussed in relation to the problem of clearing this type of vegetation.

If the object of clearing *miombo* is to produce pasture then it is evident that removing the larger trees alone is not the only operation that is necessary. As soon as grass fires are prevented and the grass is grazed the numerous seedlings and suckering shoots normally present between the trees, together with the regeneration appearing as a result of clearing, will no longer be suppressed and, unless further control measures are taken, will soon provide a serious bush encroachment problem. The use of 2,4,5-T to kill the trees will undoubtedly stimulate much less regeneration than felling but it will not entirely prevent it and the growth of the fire-suppressed shoots will be unaffected. It is possible that a foliage spray applied to these shoots and to the regrowth would be sufficient to provide control but there is so far no experimental evidence of this and there is little doubt that periodic spraying or burning would be necessary to maintain control for a long period.

Where clearing is to be carried out for tsetse-control purposes without immediate settlement of the area, regeneration is of less importance as the annual fires are not interrupted. For barrier clearings designed to prevent tsetse movement, where all the trees in a belt of country must be killed, it is probable that treatment with 2,4,5-T would compare favourably in cost with felling. For many species, however, including most of the larger trees such as *Brachystegia*, *Pseudoberlinia* and *Burkea*, it has been found that careful ring-barking is effective, quicker and considerably less expensive than felling. It also appears to be considerably cheaper than treatment with chemicals and, although these kill a larger proportion of the total number of trees, the difference is unlikely to be great enough to outweigh the difference in cost.

The situation is rather different when discriminative clearing is considered. This operation aims at destroying tsetse-concentration sites and only involves the clearing of a small proportion of the total area (Buxton, 1955). The areas cleared are mostly along the edges of drainage lines where there is a zone of smaller trees between the *miombo* woodland and open grassland. These smaller trees, including such species as *Combretum guenzii*, *C. ternifolium* and other *Combretum* species, *Terminalia sericea*, *Pseudolachnostylis*, *Hexalobus* etc., are mostly resistant to ring-barking and normally have to be cut down. The majority of these species appear to be susceptible to 2,4,5-T treatment

and it is for this type of clearing that arboricides are most likely to be of value in *miombo* country.

SUMMARY

An experiment was carried out at Urambo in Tanganyika in which esters of 2,4,5-T, 2,4-D and a mixture of the two were applied as basal bark sprays to tree species of *Brachystegia–Pseudoberlinia* woodland (*miombo*). The trunks were frilled before spraying and the responses of the trees were observed over a period of nearly three years.

2,4,5-T at a concentration of 2·0 per cent (w/v) of acid killed the above-ground parts of more than 90 per cent of the trees. A concentration of 1·0 per cent was slightly less effective. 2,4,5-T was slightly more effective than 2,4-D or the mixture but the differences between chemicals and concentrations were small.

Chemical treatments in general killed a greater number of trees than ring-barking and also had a greater effect in preventing regeneration. The chemicals did not entirely prevent regrowth and coppice or sucker growth occurred with 20 to 30 per cent of the affected trees, including a larger proportion of *Pseudoberlinia*.

Emulsions of 2,4,5-T gave somewhat lower top-kills than oil solutions but were equally effective on *Pseudoberlinia* and *Brachystegia* and had considerably more effect than has been found in most other trials on East African trees species.

Additional experiments confirmed the susceptibility of *Brachystegia* and *Pseudoberlinia* to esters of 2,4,5-T and 2,4-D in oil solution but showed that the chemicals were ineffective without frilling. The effectiveness of emulsions of 2,4,5-T in water was not confirmed. In one trial on *Pseudoberlinia* a concentration of 1·0 per cent of 2,4,5-T in oil gave a complete kill and no regeneration was noted in 20 months after the treatment.

The results are discussed in relation to the ineffectiveness of arboricides against *miombo* species reported in other parts of Africa and in relation to their practical utilization in Tanganyika. It is concluded that they are most likely to be of value in the discriminative clearing of bush for the control of tsetse.

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The Composition and Digestibility of Some Conserved Fodder Crops for Dry Season Feeding in Ghana

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PART II. SILAGE

Among Ghanaian cattle farmers, silage-making is virtually unknown. On Government agricultural stations, silage has been made with varying success and with varying capital outlay on towers, clamps, pits and trenches.

Technically silage-making does not present any great difficulties, once siting problems are overcome, and it seems to be a more promising form of fodder conservation than hay-making under the humid conditions prevailing over much of the Accra Plains. The siting of pit and trench silos does require a good knowledge of soil and run-off conditions where torrential rainstorms are likely to occur.

The technical knowledge and capital required for silage-making are far beyond the reach of the native cattle owners or their cattlemen, who are unlikely to be prepared to invest in the necessary machinery even if the capital were available. These are socio-economical problems and as such are beyond the scope of this article. None the less, if the savannah grassland of Ghana is to be fully utilized, then fodder conservation in one form or another is needed. Whether it is by cooperative effort, by contractors or by Government machinery pool is a problem for the development authorities.

At the Government Animal Health Station at Nungua on the Accra Plains, Guinea corn (sorghum) and millet (*Pennisetum*) silage have been made successfully for a number of years, both in sunken tower silos and trenches.

The author was able to carry out trials with guinea corn silage at this station by courtesy of the Director during 1954–55. More recently, trials with millet silage have been completed at the Agricultural Research Station of the University College at Nungua. Trials with maize–legume mixture silage had to be abandoned due to a serious skin infection which caused loss of condition in the experimental animals and there was lack of agreement between individual animal's digestion coefficients. These trials with cereal–legume mixtures are being repeated and will be reported at a later date.

EXPERIMENTAL PROCEDURE

The experimental procedure and animals used were the same as in Part I (1958) of this study except that in the millet silage experiments, three White Fulani cattle were added to the group.

DESCRIPTION OF SILAGE USED

Guinea corn (*Sorghum vulgare*) was ensiled in a small trench silo. The Guinea corn was of the very tall, long growing-season type found in the Northern Territories from where the seed undoubtedly reached Accra Market and ultimately Nungua. This Guinea corn will reach a great height, sometimes as much as fourteen feet. In this case it was harvested at about eight feet high before shooting ear. The green leafy material was packed longways into the trench without being chopped. When opened the silage was in good condition and readily eaten by the bullocks.

Fodder millet (*Pennisetum typhoideum*) was ensiled in a large trench before shooting ear at about six feet high. The material was in green leafy condition and was chopped prior to packing in the trench. In the first batch, heavy rains caused considerable spoilage due to lateral movement of water through

Figure 1. Silage trench at Nungua, with open face temporarily protected against rain. Note ample drainage cut to carry away foreign water

the soil into the pit presumably through cracks in the soil walls (see *Figure 1*). The resulting material had a damp butyric smell and a dark rather slimy appearance. Although eaten by cattle it was obviously not very palatable.

The second batch of millet silage was made successfully in an improved trench and, when opened, had a slightly acid fruity smell and a good light brown colour. The bullock ate the silage readily (*Figures 2* and *3*).

RESULTS AND DISCUSSION

Tables 1 and *2* show the chemical composition, digestible nutrients and digestion coefficients of the silage examined. The digestion coefficients for the poor quality millet silage in *Table 2* were obtained from a trial using three of the so-called Gold Coast Shorthorn cattle and three White Fulani

cattle (Zebu). It can be seen that the coefficients obtained with the Fulani cattle were higher than those obtained with the Shorthorns. These differences were not found when the good quality millet silage was used.

Figure 2. White Fulani bullock

Figure 3. Gold Coast Shorthorn bullock

Differences in power of digestion between Zebu and non-Zebu cattle have been discussed by FRENCH (1940) who found no difference between East African Zebu cattle and 7/8 grade Ayrshires. DUCKWORTH (1946) in a

statistical analysis of Indian vs American and European digestion trial results, found significant differences. It was suggested by FRENCH (1956) that the differences may have been due to the different rates of lignification of tropical feeds. Since there is no direct evidence of different digestive power between Zebu and non-Zebu cattle, it would be wrong to consider the results of this trial as more than a slight indication that such differences may

Table 1

Feed	*Dry matter*	*Crude nutrients, per cent*			
		Crude protein	*N-free extract and fat*	*Crude fibre*	*Ash*
Guinea corn silage	24.4	2·1	11·6	8·2	2·5
Poor quality millet silage	22·9	1·1	13·3	6·6	1·9
Good quality millet silage	25·0	1·4	12·3	9·2	2·1

Table 1 (contd)

Feed	*Digestible nutrients, per cent*				
	Crude protein	*N-free extract and fat*	*Crude fibre*	*Starch equivalent*	*Nutritive ratio*
Guinea corn silage	1·3	7·2	6·2	11·5	9
Poor quality millet silage	0·3	6·5	3·6	8·6	29
Good quality millet silage	0·4	8·3	6·6	12·7	32

Table 2. Digestion coefficients

Feed	*Dry matter*	*Organic matter*	*Crude protein*	*N-free extract and fat*	*Crude fibre*	*No. of animals*
Guinea corn silage	63·9	66·7	61·9	61·7	75·7	2 *Shorthorn*
Poor quality millet silage	45·4	51·4	22·1	48·4	53·0	3 *Shorthorn*
	50·2	53·4	30·5	49·0	55·0	3 *Fulani*
Good quality millet silage	62·7	69·4	27·2	67·2	72·0	6 (3 *Shorthorn* +3 *Fulani*)

exist in West Africa where we have apparently indigenous or at any rate long established Zebu and non-Zebu cattle. None the less the author has initiated a direct comparison between Zebu, Ndama and Muturu cattle in order to cast more light on the subject.

The starch equivalent values for the two millet silages are probably representative of the worst and best silage likely to be made by contractors or Government station staff. The nutritive ratio in both cases is excessively wide. The Guinea corn silage is a little better and could possibly maintain a West African bullock and even support production of flesh.

It is quite clear, however, that although these silages, like the hays described in Part I (1958), may supply sufficient energy, they are too low in protein to be of real benefit to animals as a supplement to dry season grazing since the grassland itself is already seriously deficient in digestible protein.

There is an obvious need for the introduction of legume crops which will grow satisfactorily on rain-fed land under the relatively dry conditions of the savannah grassland where these conserved fodders are required. A possible alternative would be the use of feed urea either as a straight supplement to these carbohydrate-rich roughages or with easily grown starchy crops such as cassava which does well on the Accra Plain soils.

CONCLUSION

The three silages made from rain-fed cereal crops on the Accra Plains could provide adequate energy but are too low in digestible protein. Protein-rich crops or feed urea-type of supplement should be introduced.

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Book Reviews

FLORA OF WEST TROPICAL AFRICA

(VOLUME I, PART II)

J. HUTCHINSON and J. M. DALZIEL. 2nd ed. revised by R. W. J. KEAY. Crown Agents: London, 1958. 828 *pp.* (illus.) 55*s*

The first edition of *Flora of West Tropical Africa* was prepared at Kew by Drs HUTCHINSON and DALZIEL and was published during the decade 1927–36. It was the first of the modern regional floras of tropical Africa. I found it of great use in Uganda. After the first edition went out of print, Mr KEAY was seconded from the Nigerian Forest Department to Kew in 1951 to undertake the revision of the *Flora*, the cost being shared by the four British West African governments, Mr Keay is very competent to carry out this revision as he had worked in Nigeria for a number of years and already possessed an extensive knowledge of the flora of the region both in the field and in the herbarium. The revised Volume I, Part I was published in 1954; now Part II, completing Volume I, has appeared, thus bringing the dicotyledons up to the family Umbelliferae in Hutchinson's system of classification.

As Sir EDWARD SALISBURY points out in his foreword to Part I, 'It is important to emphasize that any *Flora* is an attempt to portray existing knowledge at the time of its production. It can never be definitive, and the more it brings into prominence the gaps in our knowledge that need to be filled, the more successful it may be deemed to be. Many groups need revision, but only the more urgent of these tasks can be undertaken in any *Flora*, otherwise publication would be so long delayed that students would be deprived of an essential tool, and much of the information would be out of date by the time the work appeared. A *Flora* is therefore of necessity a compromise between what is theoretically desirable and what can in practice be achieved. But even more it is inevitably a temporary assessment of an everchanging scene which, the more successful its objective, the more rapidly will it become out of date by the stimulus it has provided towards further floristic studies of the area.' It is hoped that this edition will provide a stimulus to further collection and investigation of the plants of West Africa.

The area covered by the *Flora* is the British West African territories, Liberia, the French and Portuguese territories south of latitude 18°N, to Lake Chad, and Fernando Po. In the first edition the area extended to the Tropic of Cancer. Consequently, a number of Saharan species are excluded from the new work. Nevertheless, much new material has been added. This is shown in the increased length, from 523 pages in the first edition to 828 pages now. If one takes an individual genus such as *Crotalaria*, 36 species were listed in the first edition and this number is now increased to 51. New genera are included, such as the monotypic *Medusandra*, which is the type of the new family Medusandraceae (Brenan, 1952), and *M. richardsiana*

is given two full pages of illustrations. The additional illustrations of this and other plants, mostly by Miss STONES, are a welcome feature of the new edition.

I have long felt that the divorce which sometimes exists between the agriculturist and botanist is to their mutual disadvantage. The agriculturist, chemist, anthropologist and others often fail to give the plants they mention in their writings their correct scientific names, thus reducing the value of their work. With the publication of this second edition workers in West Africa have no excuse for such omissions. The work should be of the greatest value to all those who wish to assess and develop the natural resources of this vast area. I believe that ecological studies in the widest sense provide the only sound bases for the preparation of rational plans of land utilization; this *Flora* will be of great help in this work.

Botanists, foresters, agriculturists, and all those who are, or should be, interested in West African plants owe Mr Keay a great debt for his thorough and competent revision. We look forward to the publication of Volume II, which we hope will not be too long delayed, just as we look forward to the publication of further families of the *Flora of Tropical East Africa*, which is in active preparation at Kew. As many West African plants are to be found throughout tropical Africa as a whole, in fact many of the weeds are pan-tropical, workers in Central and East Africa will find this second edition of the *Flora of West Tropical Africa* useful until such time as *Floras* of their areas are completed.—J.W.P.

GENETICS AND THE IMPROVEMENT OF TROPICAL CROPS

Sir JOSEPH HUTCHINSON. Cambridge University Press: London, 1958. 30 *pp.* 3*s* 6*d*

Sir JOSEPH HUTCHINSON, C.M.G., Sc.D., F.R.S., is the most distinguished Associate of the Imperial College of Tropical Agriculture. Since completing his post-graduate training in 1929 he has been on the staff of the Empire Cotton Growing Corporation in Trinidad and Uganda, where he has been Director of the Cotton Research Station at Namulonge since 1949. From 1933–37 he was attached to the Institute of Plant Industry at Indore in Central India. His appointment as Drapers Professor of Agriculture in the University of Cambridge in 1957 gave great pleasure and encouragement to those of us who are working in the agricultural field in the tropics. This pleasure and encouragement was further increased when he chose as the subject of his inaugural lecture ' Genetics and the improvement of tropical crops '. In his opening paragraph Sir Joseph states that ' a knowledge of the genetics of tropical crops is a sound base from which to launch an incursion into the field of applied genetics in temperate regions '. This may come as a surprise to many, more particularly when they consider the paucity of plant breeders and agricultural research workers in the tropics.

As is to be expected, Sir Joseph, who has added so much to our knowledge of the genus *Gossypium*, draws extensively on the cottons for his examples, but work on other crops is discussed, including groundnuts, sorghums and maize. He refers to VAVILOV's theory of the variability of a crop plant being greatest near its centre of origin and then shows that the distribution of

variability in a crop is dependent upon the nature of the breeding system. In outbreeding crops, even when only 15 to 20 per cent natural crossing occurs, new centres of variability are developed in the many regions in which the crops have been established. Even in pre-eminently self-fertilized crops such as wheat there is enough crossing in Northern India, which is one of Vavilov's centres for the wheat plant, to give a degree of heterozygosity in excess of what would be expected in long inbred material. Sir Joseph believes 'that self-fertilization is a recent, and unfortunate, accident' in a crop's history.

The first two thirds of the lecture is concerned with 'the problem of genetic variability, its origin, distribution and above all its conservation', to which Sir Joseph attaches the greatest importance for all future breeding work. He then goes on to show the importance of making a precise and definitive objective in all breeding work. The most successful breeding projects have been achieved in East Africa where this has been done, e.g. transferring the resistance to *Puccinia polysora* to local African maize types by STOREY *et al.*; transference by DOGGETT of the hard corneous layer, which gives weevil resistance in the late sorghums, to the early sorghums, which are important in the prevention of food shortages in the Lake Province of Tanganyika; MANNING's success in breeding long-term, late-fruiting types of cotton, as high yields in Uganda are dependent on early sowing and a long growing season; and PEAT's breeding jassid-resistant cottons. Finally Sir Joseph shows the important part the plant physiologist has to play in the definition of breeding objectives.

Many of us who have worked in Africa have long felt that improved farming methods, the use of fertilizers etc., have a big part to play in increasing crop production by peasant farmers. Improved varieties produced by the plant breeder often do not get a chance to show their capabilities due to the low level of cultivation. Many pessimists today paint the dreadful picture of food reserves failing to keep up with the alarming rate of increase of local populations. It is encouraging that Sir Joseph concludes his lecture by saying that 'the improvement of farming practice may well provide opportunities for as great a varietal improvement in the second half of this century as took place in the first half'.

I seem to have given a very long review of a very short work, but it has been a pleasure and privilege to do so. I only hope that the price of 3*s* 6*d* for thirty small pages of large print in a paper cover will not debar all who have the interests of tropical agriculture at heart from reading and re-reading this lucid, erudite and stimulating lecture.—J.W.P.

TEA

T. EDEN. Longmans, Green: London, 1958. *xvi*+201 *pp.* (illus.) 35*s*

This excellent book is a most welcome addition to the Tropical Agriculture Series which Messrs Longmans, Green & Co. are publishing with the encouragement and help of the Colonial Advisory Council of Agriculture, Animal Health and Forestry—a series which shows every promise of going far towards remedying the present paucity of authoritative and up-to-date texts on the major crops of the tropics.

In his preface the author makes it clear that he has not attempted to write an encyclopaedic account of the industry, dealing in detail with tea production in all the major producing countries, nor to write a planting manual specifically for a given region, but has adopted the more valuable course of writing a descriptive account of the various stages of tea cultivation and manufacture on which to base a discussion of the principles involved. In this he has succeeded admirably: his long scientific and practical experience of the industry, combined with an ability to write clearly, has enabled him to give a most lucid and concise account of the principles of tea production and manufacture in a book of only moderate length.

The book covers the climatic and soil requirements of the crop and its botanical characteristics, the selection and propagation of planting material, land preparation, planting, pruning and plucking, cultivation, manuring, shade, pests and diseases, the chemistry of the tea leaf and its manufacture, and ends with chapters on the tea trade and industry and a statistical review of production and consumption. It is well illustrated and indexed.

Many of the matters discussed—for example, the use of shade trees, the principles underlying soil cultivation and management, and the importance of really careful and high quality work during the planting and establishment of the crop —are of direct relevance to the culture of a number of other perennial tropical crops besides tea. Dr EDEN's clear and authoritative exposition of these matters can therefore be recommended to the attention of those concerned with all such crops and indeed to all interested in tropical agriculture. To those engaged in tea culture, particularly in countries where it is a recent development and where the absence of long local experience makes a clear understanding of principles all the more necessary, this book should prove of great interest and value.—C.C.W.

PIG CARCASS EVALUATION

G. HARRINGTON. Commonwealth Agricultural Bureaux: Farnham Royal, Bucks, 1958. *xi*+107 *pp*. (illus.) 15*s*

This highly technical and comparatively highly priced monograph makes a very valuable contribution to our knowledge of the pig and bacon trades.

Pig grading, both on the farm, at the agricultural show and in the abattoir, is growing in importance in most countries of the world and an objective appraisal of the various methods in use, and their relative significance, is long overdue. Dr HARRINGTON's review fills this gap in the literature.

As the author points out in the opening paragraphs of his ' discussion ', the book is not as completely critical as is perhaps desirable. For instance, even the modest approach demanded by scientific impartiality could have enabled the author to have been a little more specific on page 21 concerning the uselessness of the liver weight:muscle weight correlation as a practical index of carcass leanness. There is abundant evidence in the literature concerning the effect of plane of nutrition on liver weight and size in all farm animals, and many workers have shown liver weight to be one of the most variable components of growth analysis data.

The author does not always make it clear to the reader whether any given

evaluating technique is designed for purely experimental use or for practical trade purposes. For instance, most workers regard the 'sample boring' technique as an experimental tool rather than as a possible practical test with general applicability to the meat trade. Had this been made clear on page 17, there would have been no need for the author to comment somewhat naively on page 18 'in bacon-producing countries, moreover, the method could not be of much practical value, because the presence of holes bored through the carcass would result in financial loss'.

The author tends to bias his work towards theoretical statistical calculations of various carcass samples and carcass measurements and at times glosses too lightly over the all-important practical aspects of actually obtaining the samples in question and making the measurements on the carcass. For instance on page 45 we are informed that 'in selecting samples of meat from carcass for tenderness appraisal the cut from which they are taken is of great importance'. Few laymen will get past the opening paragraphs of this publication and the technical reader will expect more 'meat' than this from such a monograph! From what site or sites should samples be obtained? At what room temperatures? How long after slaughter? How long a fast is desirable? These are the practical problems uppermost in the minds of workers in this field and it would have been more helpful if the author had made some practical recommendations, however tentative, with a view to a greater degree of standardization of the different methods now in use.

A small point of criticism is that the references cited are not dated in the text, as is the usual practice. The C.A.B. are to blame here rather than the author, as there is no standardization of procedure in this respect even amongst the limited number of technical publications published by the Animal Breeding and Genetics Branch of the Bureaux. The technical reader will be familiar with many references at a glance, and the addition of the date after the author's name would save him the trouble of confirming whether a given reference concerned a well known paper of several years' standing or whether it concerned a new paper which had escaped his attention or which was 'in press'.

The monograph is very poorly illustrated. Diagrams giving full details of the major porker joints and of the different bacon cuts are surely called for in a work of this nature, and an illustrated comparison of American, Scandinavian and British methods would be most welcome. The reviewer is perhaps either childish or old-fashioned, but he would at least welcome one picture of a pig in a book about pigs.—P.N.W.

PRINCIPLES OF PLANT PATHOLOGY

E. C. Stakman and J. G. Harrar. The Ronald Press Company: New York, 1957. *xi*+581 *pp.* $8.00

This excellent books deals, as its simple title indicates, with the principles of plant pathology. However, the simplicity of the title belies the wealth of experimental research with which the authors have illustrated these principles. The pathogens that are met with in these pages are not isolated organisms living an artificial life in the laboratory, but appear as part of the

ecological balance within which man is engaged in his fundamental occupation, agriculture.

This deliberate emphasis on the pathogens of food-producing plants ' because of the importance of these plants to society and to the growing demand for increased production of basic foods throughout much of the world ', is maintained all through the book. After discussion for the first two thirds of the book of the pathogens themselves, their classification, their growth and reproduction, their genetics, and their epidemiology, there are chapters on diseases of international importance, diseases in transport and storage, and four chapters on crop protection by quarantines, cultural practices, chemical control, and resistant varieties.

The book is well produced, and there are a large number of excellent photographs. Each of the eighteen chapters has a list of references, including many review articles; there are three appendices listing important books on plant pathology, the principal pathogens and principal insects cited in the text; and, besides the full subject index, there is an author index giving both the page of citation and that of the reference.—R.F.B.

COTTON ATLAS OF INDIA 1957

Indian Central Cotton Committee: Bombay. *iii*+100 *pp.* (illus.) *Rs* 15

This is a well printed and illustrated statistical guide to the production and consumption of cotton throughout the world, with principal emphasis on India. There is also a series of maps showing physical features, soil, rainfall and communications in India.—A.L.J.

COPRA PROCESSING IN RURAL INDUSTRIES

A. Aten, M. Manni and F. C. Cooke. *F.A.O. Agricultural Development Paper No. 63.* F.A.O.: Rome, 1958. *viii*+122 *pp.* (illus.) 7*s* 6*d* or $1·50

This publication must rank as one of the best of its kind so far produced. The authors have selected material for inclusion in the book with admirable discrimination and the result has been a well balanced reference book for the use of field workers concerned with extension work among copra producers. It provides detailed information on the preparation of good copra by methods suitable for use by either small peasant producers or those producing large quantities of copra on estates. Attention is particularly drawn to the importance of producing better copra by peasant producers, who it is stated produce over 90 per cent of the world's supply of copra.

The book is well illustrated with photographs, and adequate plans and specifications have been included for building a wide range of types of copra driers. There is also included a good selection of tabulated information relative to copra production.

As the authors have stated in their foreword, this book has been published for the use of those concerned with the practical side of copra production. It can also be thoroughly recommended for the use of students as introductory reading and the long list of references at the end of the book will give ample scope for further reading on subjects relative to the utilization and processing of coconut palm products.—W.J.B.

THE OWNER CULTIVATOR IN A PROGRESSIVE AGRICULTURE

K. H. Parsons. *F.A.O. Agricultural Studies No. 39.* F.A.O.: Rome, 1958. *vii*+66 *pp.* 2*s* 6*d*

There is hardly a matter in agricultural planning today that raises so much emotional and political dust as land reform. In a number of countries in recent years technicians and politicians have been swept into enormous programmes of land reform by a wave of emotional fervour. In by no means every case have the instigators of such schemes realized the extent of the revolution they propose, the problems they will have to surmount and the further problems they are likely to create. Many such programmes have subsequently had to be consciously retarded or have lost momentum from the disillusionment of the first beneficiaries.

Emotion and politics are always likely to play an important, if not uncontrollable, part in programmes such as land reform which are expected to benefit the little man at the expense of the big. It is therefore essential that the economic arguments for and against such reforms, the conditions under which they are likely to stimulate economic progress and the numerous obstacles to the achievement of those objects should be readily available to all administrators who may have to assume responsibility for such programmes. This little booklet, which has been prepared partly as the manual for F.A.O. advisers, fills this most vital need admirably.

Without being ponderous, or for that matter superficial, it brings out clearly various aspects and problems of owner cultivatorship as a mainspring of progressive farming. It places, as it should, the discussion essentially in the context of economic and agricultural development. Its message is clear and sound: the owner cultivator can serve as a foundation and a generator of rapid economic development as in fact he did in the United States of America; but the mere act of creating such cultivators, particularly in undeveloped countries where this class has not previously or for centuries existed, will not in itself create progress and may in the wrong circumstances perpetuate economic inefficiency and stagnation.—A.L.J.

ADDENDUM

NEW APPROACH TO FERMENTATION OF WEST AFRICAN COCOA

The authors (H. W. S. Allison and T. A. Rohan) wish to point out that the quality assessments mentioned in their article (*Trop. Agriculture, Trin.* **35**, 1958, 287) were made unofficially by the various manufacturers, as well as by the W.A.C.R.I. panel. Official assessments of Tray Fermentations are being made and the results will be published in the near future.

OBITUARY

Dr Mary V. F. Gianetti

It is with great regret that we have to record the death in London on 18 August 1958 of Dr Mary V. F. Gianetti, College Medical Officer of Health and wife of Mr G. G. Gianetti, Dean and Registrar at the Imperial College of Tropical Agriculture.

Having qualified at Glasgow University, Dr Mary Beattie first came to I.C.T.A. with a Wandsworth Scholarship to study mosquito breeding places in the tropics and later the problem of malaria in connection with rice cultivation.

She and Mr Gianetti were married in 1931. From 1940 until her death, with a break of two years, she was College Medical Officer of Health. She endeared herself to staff, students and employees by her cheerful disposition, efficiency and obvious concern over the health of each and all, and maintained a high standard of hygiene and sanitation at the College. She served on the Trinidad Board of Education, Nutrition Committee and Medical Board. From 1939 to 1945 she was Vice-President of the Northern Division of the Trinidad Branch of the Red Cross Society. Her great war effort with the Red Cross undoubtedly consisted of the part she played in organizing Hilcote, a convalescent home in St Augustine, for survivors from ships sunk by enemy action, who will remember her with gratitude.

She was, like her husband and children, an excellent tennis player. The hospitality of her happy home, and the friendliness and advice of her husband and herself were appreciated by many generations of students.

We offer our sincere sympathy to her husband and two children.

Recent Publications

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

Memoirs—Economic Series No. 2: Peasant Farming, 1*s*; No. 3: Readings in Small Scale Farming, 5*s*; No. 4: Clip-Card Accounting on the Farm, 8*s* 4*d*

A Notebook of Tropical Agriculture. 6th ed. rev. and enl. 1957. 12*s* 6*d*

THE REGIONAL RESEARCH CENTRE OF THE BRITISH CARIBBEAN

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Reprints are available, at varying prices, of articles in these reports, including the Colour-Illustrated Guide to the Diagnosis of Mineral Deficiencies in Cacao, 5*s* plus postage

Soil and Land-Use Surveys (with maps)—

No. 1 Jamaica. Parish of St Catherine 1958, 20*s*

No. 2 British Guiana. The Rupununi Savannas 1958, 15*s*

No. 3 St Vincent (in press)

OTHER PUBLICATIONS

Flora of Trinidad and Tobago. (The early parts were edited by the Department of Agriculture of Trinidad and Tobago but editing has now been taken over by the Botany Department of the Imperial College. The Flora may be obtained from either address.)

Volume I—Ranunculaceae to Araliaceae (8 parts and index), 26*s* 6*d*

Volume II—Rubiaceae to Labiatae (6 parts to date), 23*s* 7½*d*

Further parts are in preparation

These and earlier publications can be obtained from the Library and Publications Department, Imperial College of Tropical Agriculture, Trinidad

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The following book written by a member of the staff has recently been published:

Insect Life in the Tropics, by T. W. Kirkpatrick. Longmans, Green: London. 35*s*

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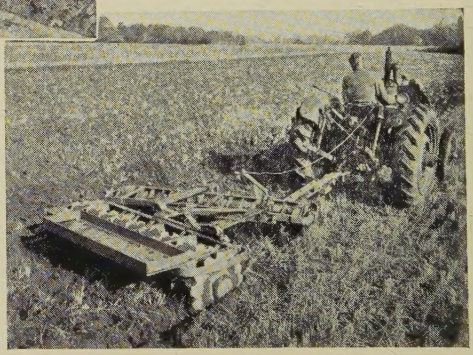

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NUTRITION of the LEGUMES

Proceedings of the University of Nottingham Fifth Easter School in Agricultural Science 1958

Edited by Professor E. G. Hallsworth

The contribution of legumes to the maintenance of soil fertility has been of peculiar interest to agricultural scientists since the pioneer researches of Boussingault in the 1870's. The supply of available nitrogen is so commonly a limiting factor in plant growth that the almost unique ability of leguminous plants to draw on atmospheric nitrogen (hence to be largely, if not entirely, independent of soil nitrogen) is of the greatest importance in the development of economic cropping systems.

Agronomists, bacteriologists, botanists, biochemists, soil chemists, horticulturalists and geneticists attending this Fifth Easter School reviewed and discussed the considerable advances made in this field of research during recent years. This collection of 24 papers provides an invaluable and stimulating source of new data for those investigating this field of biology. *Price 55s.*

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